AUSTRALIAN BUILDING PRACTICE

JAMES NANGLE


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AUSTRALIAN BUILDING PRACTICE.

A TREATISE FOR AUSTRALIAN STUDENTS OF BUILDING CONSTRUCTION.

BY

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ILLUSTRATED BY NUMEROUS PHOTO-ZINC BLOCKS
FROM DRAWINGS BY THE AUTHOR.

PART I.

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PREFACE.

THE matter contained in the following pages was originally prepared in the form of notes for instruction to students in the Building Construction Class formerly under the Author's charge at the Newtown Technical School. The notes were afterwards amplified and re-written in the form of articles for publication in the pages of the "Building, Engineering and Mining Journal," from which they have been reprinted in the present form.

The Author is not aware of the existence of any work devoted to the description of the materials and methods of Australian building construction. He therefore hopes that this little book, even though he cannot but feel that it has many shortcomings, will be found to be of some use, not only to students, but also to Architects and Builders.

The Author has endeavored to acknowledge in the text the sources of the information which he has used. He, however, wishes to especially acknowledge his indebtedness to Professor Warren, of the Sydney University, and Mr. J. H. Maiden, Government Botanist of New South Wales, from whose published works much valuable information has been obtained. He is also greatly indebted to Mr. R. T. Baker, Curator, and Mr. G. H. Smith, Asssistant Curator, of the Technological Museum at Sydney, who have been at all times ready to give information about the specimens in the invaluable Institution under their charge. He is very grateful to these gentlemen, and also to the many of his friends who by advice and suggestions have helped in the preparation of these articles.

Sydney,

August, 1900.

ERRATA.

Page 2.—The title of Art. 9 should be: Determination of two or more forces to balance a single force.

Page 67.—Line 9 from the bottom : Figure 54 should read Figure 45.

Page 82.—The Bacchus Marsh Stone, No. 13 in the table, should be classed as a sandstone. See the description of it in Art 254, page 77.

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AUSTRALIAN BUILDING PRACTICE.

PART I.

CHAPTER I.

EQUILIBRIUM OF FORCES.

THE principles underlying the treatment of such forces, and their effects, as occur usually in building construction are described in this, and in Chapter II. Necessarily these principles are dealt with in an elementary way, and the cases given as examples are such as are most frequently met with in practice.

2 THE forces which are, under ordinary circumstances, to be dealt with in building construction are:—

(*a*) Force of gravity or weight.

(*b*) Force of wind.

3 FORCE OF GRAVITY.—The earth has the power of attracting all smaller bodies to it, and the direction of attraction is towards its centre, or along what is called the " plumb line." This power of attraction, when bodies are in a condition of apparent rest, is not evident, but it is nevertheless being exerted. A brick wall on a rock foundation does not move towards the centre of the earth because of the resistance of the foundation on which it is built, there being a constant balance maintained between the gravitation tendency of the wall and the re-action or resistance of the rock. Ample evidence of this power will, however, be obtained in the case of the settlement of a wall, built on a mud or quicksand foundation, or in the case of the collapse under an imposed weight of an insufficiently strong column or girder.

4. WIND—The force of the wind does not enter much into the calculations for ordinary building work, but in the case of very tall buildings, towers, spires, chimneys, and large roofs, it is a force that must be guarded against for at times its power is most destructive.

5. DIRECTION AND MAGNITUDE OF FORCE.—The direction of a force may be indicated by a straight line, and its magnitude thereon, in units of weight as lbs. or tons, to some linear scale. An example of units of weight set out to a linear scale would be :— 10 tons to 1 inch.

6. EQUILIBRIUM.—The line A B in Fig I. is the line of direction of a force acting at the point A. A directly equal and opposing force is represented by the line A C also acting at the point A, and counteracting the effects of the force A B. Therefore it will be evident that the point A. is in a state of rest, or as it is called, equilibrium.

7. RE-ACTION.—What is termed re-action may next be considered. For example, let the line A B, Fig. I. represent the external force that we would exert with our hand at a point A, on the surface of a piece of stone or some such material Our hand does not press into the stone because the force A B, which we exert at A, is met by an equal and opposite force A C brought into play by the resisting power of the stone, and which counteracts the influence of force A B. This counteracting force is called the force of re-action, and will be exerted up to a certain limit by all bodies ; that is to say, any body will exert a re-active force equal to any impressed external force, that does not exceed the limit of resistance of the body. An example will perhaps remove any risk of this not being understood. Let the force A B = 1 ton, then the body on which it acts will exert in opposition a re-action of 1 ton only, although the body is, we will suppose, capable of exerting a re-action of 10 tons. And so on, re-action will be exerted by this particular body for any external force that does not exceed 10 tons. Should a force of 11 tons be imposed at A collapse (in the case of the body above assumed) must take place on account of the insufficiency of re-action.

8. DETERMINATION OF THE FORCE WHICH WILL BALANCE TWO GIVEN FORCES.—Let A B and A C, Fig. 2, be the lines of direction of two forces which meet at the point A. The force A D. which will balance them or maintain equilibrium, may be determined by its magnitude and direction as follows :—Draw a line U T parallel to and equal in magnitude to AC. From T draw a line TS parallel to and equal in magnitude to AB. Then join U S by a straight line, which will be the balancing force in magnitude and direction. The magnitudes of A B and A C can be plotted or laid down to a linear scale of tons or lbs as may be convenient, and it will be by the same scale that the magnitude of A D will be measured. The triangle S T U is called the "triangle of forces," and the law concerning it is as follows :—"The conditions of equilibrium for three forces acting at a point is that they be represented in magnitude and direction by the three sides of a triangle" A force equal and directly opposite to A D would be the resultant of the forces A B and A C,

9. DETERMINATION OF THE FORCE WHICH WILL BALANCE TWO GIVEN FORCES.—The foregoing has dealt with the balance of two forces by a single force but it may be that the force A D is known, and that it be required to balance it by two forces, the directions only of which are known. Let A B and A C (Fig 2) be the directions of the two forces which are to balance A D. Then set out U S parallel to and representing the magnitude of A D. Draw U T parallel to A C, and S T parallel to A B. Then U T will be the magnitude of A C, and T S that of A B.

10. BALANCING FORCE OF ANY NUMBER OF FORCES ACTING AT A POINT.—If a number of forces as A B, A C, A D, and A E, Fig. 3, act at point A, their balancing force may be found by proceeding much in the same manner, as in the foregoing example. Draw S T parallel to, and equal in magnitude to A B, T U to A C, U V to A D, V W to A E. Then the magnitude and direction of the balancing force will be obtained by joining W to S. The polygon so obtained is called the "polygon of forces."

MOMENTS OF FORCES.

11. MOMENTS.—The moment of a force about a point, is the measure of tendency of the force to produce rotation round the point. For example let it be supposed that the body E F G H, Fig 4, has one point in it fixed at O. It will be obvious that the force P, acting at A, will tend to turn E F G H round O in the direction indicated by the arrow M. Now let it be supposed that the force Q acting at B also tends with an equal effect to turn E F G H round O, but in an opposite direction

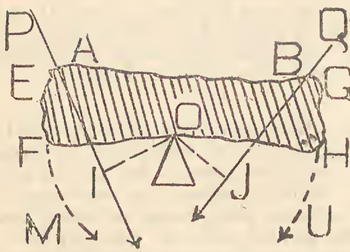


FIG. 4

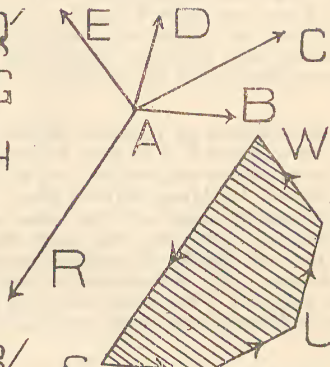


FIG. 3

FIG. 1

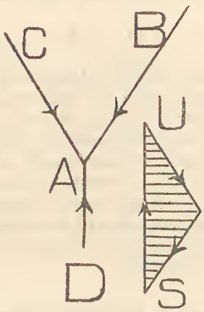


FIG. 2

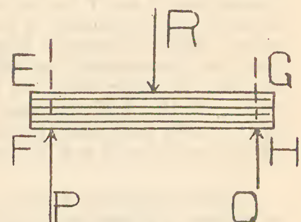


FIG. 5

FIG. 6

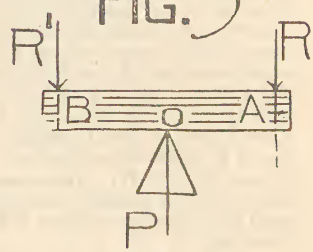


FIG. 7

(as shown by arrow U) to that of the rotation due to P. The equal but opposite effects of P and Q will therefore maintain E F G H in a state of balance about O. The tendency of P to turn E F G H round O is the moment of P about O, and is determined as follows :—Draw a perpendicular O I from the point O to the line of direction of P, then P x O I = the moment. Likewise if O J is the perpendicular to the line of Q the moment of Q will be Q x O J. If the body E F G H is balanced by P and Q then the moment P x OI = the moment Q x O J. In the example Fig. 4 it has been assumed that the balancing force of P and Q acts at O, and that P and Q are of proportionate magnitude to balance E F G H when O is a fixed point in it. The principle of moments is of great value when determining the stresses in girders, and the use in this direction will be dealt with later on.

12. Equilibrium of Parallel Forces.—If P and Q (Fig. 5) be two equal forces acting on a body E F G H, their balancing force will be a force equal in magnitude to the sum of their magnitudes, and will act in an opposite and parallel direction along the line R midway between them. Should, however, the two forces, P and Q, be unequal in magnitude, the balancing force, while being as before, equal in magnitude to their sum, will have its parallel line of direction not midway, but will divide the interval between, in the proportion that the forces bear to each other. Fig. 6 illustrates the case of two unequal forces, P and Q acting on a body E F G H. The magnitude of R acting on the point O will be P+Q, and its line of direction will divide the distance between A B at O in the following proportion :—

$$P : Q :: B O : O A.$$

13. Example of Parallel Forces.—As an example of parallel forces, let A B (Fig. 7) be a beam considered as a lever, with its fulcrum at O, and acted on at its extremities A and B by the forces R and R′. If the rod or lever is to be perfectly balanced, the moments of R and R′ about O must be equal, and with opposite effect. Let it be assumed that the moments are equal, and it can be easily seen that they are opposite, for while R tends to rotate the end A downwards towards the left, the other force R′, tends to rotate B also downwards, but towards the right. So that while O remains fixed, the rod will be in equilibrium. The fixture of O is easily provided for, because it is only necessary that the balancing force P of the two forces R and R′ should act thereat,

14. The beam is next shown, by sketch A Fig. 8, resting with its ends on piers or supports girder-wise, and supporting a weight, or force W. Reflection will make clear that the conditions are in reality the same as when it was acting as a lever in the last example. Point O may still be considered as the fulcrum and the re-actions R and R′ as the forces at the extremities A and B. The moment at O may be found graphically as follows :—Draw a line C D, parallel to force of W and equal to magnitude of W to some linear scale of lbs. or tons. Take any point G and join to C and D so as to form the triangle C D G. Drop a perpendicular G H from G on to C D. Next draw a line A I parallel to C G and cutting line of W at I. Then a line I J from I, parallel to D G, and cutting line of R′ at J. Join J A. If a line G K be drawn parallel to J A it will cut C D into two parts and give the R and R′ re-actions of W. The moment of R or R′ about O will be=G H × I P. That this will be so, is easily understood, by taking the case of R which is represented by C K. Now the triangle C K G is by construction similar to the triangle A I P therefore :—

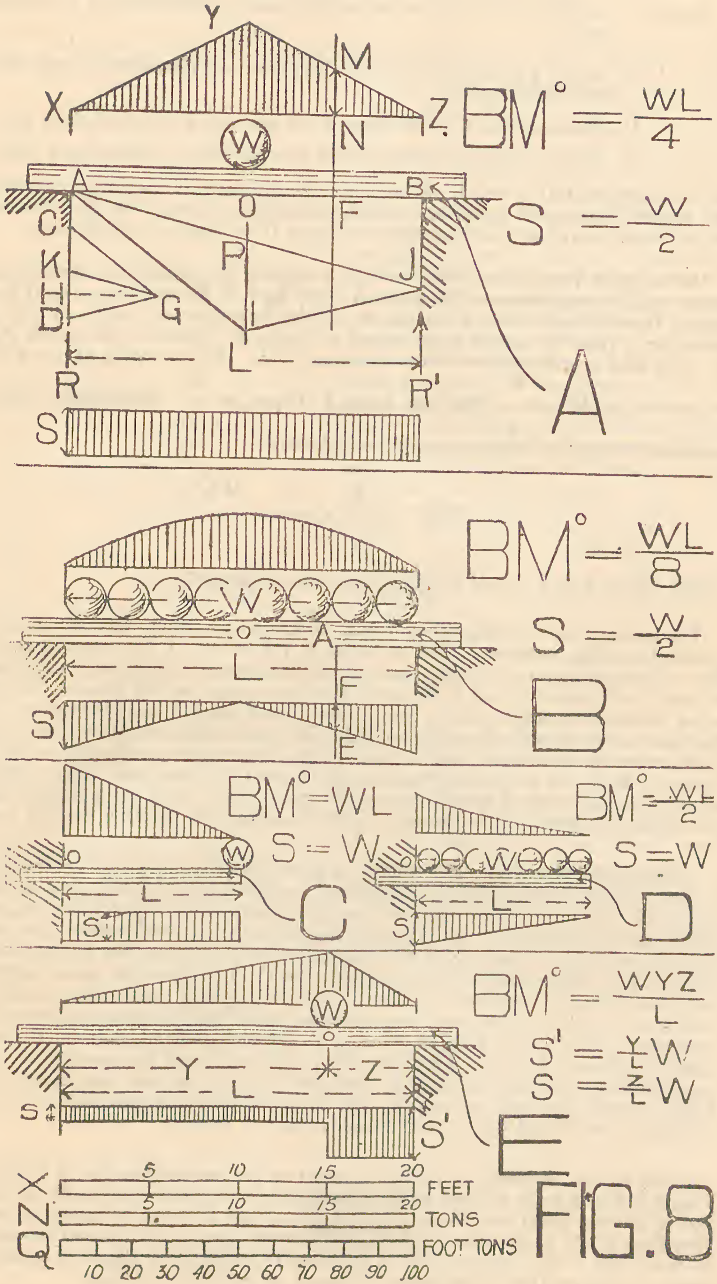
$$G H : C K :: A O : P I$$

$$\text{or } G H \times P I = C K \times A O$$

So that multiplying G H by P I will be the same as multiplying the force R by its perpendicular distance from O.

Fig. 8 illustrates a few of the ordinary cases of loaded beams.

Sketch A shows a beam supported at both ends and sustaining a load at its centre.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FOOT TONS
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FIG. 8

Sketch B shows a beam supported at both ends and sustaining a distributed load.

" E shows a beam supported at both ends and sustaining a load on one side of the centre.

" C shows a beam fixed at one end and sustaining a load at outer end.

" D shows a beam fixed at one end and sustaining a distributed load.

In the examples B C D and E the methods of obtaining the bending moments by the graphic process are not shown, but the principle is the same as that illustrated by sketch A, and it will not be difficult to apply it to these and other cases.

On the right hand side of each example is written the formula for calculating the maximum bending moment. The position of the max. B M° is indicated by O in each case. It will be sufficient to explain one of the formulae—all being on the same principle. Take the case of beam loaded at centre as shown by the sketch A Fig. 8. The load is indicated by W and the span by L. The re-action at one point of support is ½ of W, or $\frac{W}{2}$ The lever arm is ½ of span, or $\frac{L}{2}$. Multiplying these two together we get the bending moment, as follows :—

$$B\,M^{\circ} = \frac{W}{2} \times \frac{L}{2} = \frac{WL}{4}$$

which will be found set out on right hand side of sketch A.

The intermediate bending moments can be found by making what is called a diagram of bending moments. The triangle X Y Z on top of the beam in sketch A Fig. 8 is the diagram of bending moments for this beam. The base of the diagram is equal to the span of, and is set out to the same scale as, the beam. The maximum bending moment (found by the formula) is set out, to a scale of moments, above its place and is the altitude of the triangle. The perpendiculars set up from the base to the sides of the triangle will be the values of the other bending moments For instance, M N will be the bending moment at point F of the beam. The upper lines of diagrams for cases of beams shown at B and D Fig. 8 will be parabolic curves, the height of which will be the max. B M° found by the formula in each case.

15. Scale of Moments.—The trouble of multiplying G H by P I Fig 8 can be dispensed with by making a scale of moments, by which the line P I may be directly measured. It really means that the multiplication of any particular diagram is performed at the outset by multiplying the scale of tons (or whatever other units of weight that may be selected) by the perpendicular G H. The line X Fig. 8, represents 20 feet, and is called the linear scale of feet. Line N of the same length as X is the scale of, and represents 20 tons. Let it be supposed that G H = 5 feet, then G H × N = 100 the number of foot tons that a line Q of the same length as N will represent. This line Q is called the scale of moments, and the value of P I may be obtained directly from it. Of course the length of X and the number of feet it represents may be varied as desired—such as 10 feet to an inch, and so on, but it is better to make the scale of tons to the same ratio, for example if X is 20 feet to 2 inches, then N had better be 20 tons, or lbs, to 2 inches.

16 So far our calculations have been based on the assumption that A B, Fig. 8 is a rigid rod, not liable to bend under the effects of the external forces, W, R and R′. But in practice every rod, beam or girder has a limit of strength against breaking. Therefore it will be necessary to have sufficient strength at O to stand the breaking tendency due to the moment of R or R′ about O, and it is in guarding against this source of collapse that the transverse strength of girders is designed.

FORCES ACTING ON A ROOF TRUSS.

17. Parallel Forces Acting on a Braced Frame.—The triangle A B C Fig. 9, represents a frame of bars or timbers, such as an ordinary King-post-truss, acted on, and while in a rigid condition, maintained in a state of equilibrium by the parallel forces P Q S R and R′. It will be clear that the bars will be stressed, more or less, while communicating the opposing action of forces R and R′ to forces P Q S. The magnitude of the stress on each bar may be determined by preparing what is called a "Force Diagram," which really consists of a series of force triangles or polygons. The system of internal forces (brought into play by the action of the external forces) which stress the various bars may be taken as acting in groups at the points A B C D E F of the frame. Therefore what is required is the force polygon for each group, and as the groups are connected with each other, the polygons will also be joined together forming a diagram which will express the magnitude ot the whole of the forces. To prepare the diagram for the frame A B C it will be necessary to proceed as follows. Set out a vertical line G H and on it to scale lay out the magnitude P′Q′ and S′ of each of the forces P, Q, and S. The magnitude of either R or R′ will be $\frac{P + Q + S}{2}$ therefore these reactive forces will be indicated by H I and I G. Let the group R, A D and A F acting at A be taken first. R is indicated in magnitude by H I on the line G H, therefore from one end of H I draw ad, parallel to A D, and from the other end af parallel to A F and meeting ad. Then ad will represent the magnitude of A D and af, that of A F. The next group will be P, A D, F D, B D, acting at D, and P′, ad, fd, and bd, being parallel to them, will represent respectively their magnitudes. Q, D B, F B and E B compose the group acting at B, so that Q′, bd, fb and b e indicate their magnitudes. The magnitudes of forces acting at the other points E and C are found likewise. It will therefore be seen that the force diagram is really built up of a series of force triangles and polygons. The stresses in the most complex forms of braced roof trusses may be determined by this graphic method, and it will readily recommend itself by reason of the fact that it dispenses with the use of algebraical and trigonometrical calculations and that it is very convenient admitting as it does of the representation of the forces on the same drawing as that which represents the roof.

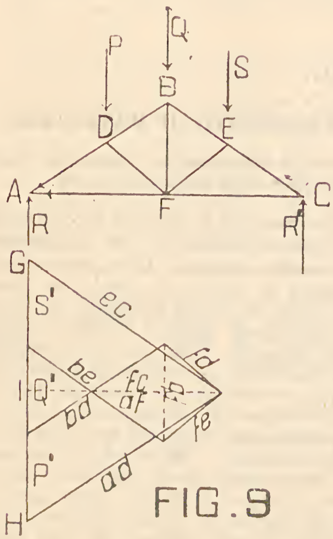


FIG. 9

CHAPTER II.

TERMS USED IN CONNECTION WITH STRENGTH OF MATERIALS.

18. THERE are certain terms, in connection with the strength of materials used in structural design, the description of which at this stage will be necessary.

19. CENTRE OF GRAVITY.—The centre of the mass of a body is its centre of gravity, and is the point through which one force equivalent to the gravitation of all its particles passes. If a point which is the centre of gravity of a body be fixed and the body be swung into any position about that fixed point, it will remain perfectly balanced. The centre of gravity may be graphically determined as follows:—Cut a piece of cardboard (of uniform thickness) to the shape of the figure, and lay it across a knife edge, arranging it so that it is perfectly balanced. Mark on it the line which is immediately above the knife edge, then turn the figure in its own plan until it is at right angles to its first position and again perfectly balanced. Mark the line of balance also. Where the two lines intersect will be the centre of gravity. Fig. 9a illustrates the operation. A B and C D being the lines about which the figure would be balanced, and O the centre of gravity.

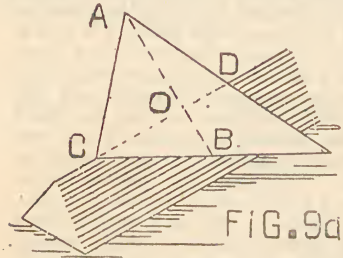


FiG. 9a

20. STRESS.—When a column, for instance, rests on a solid foundation, and supports a load, it is subject to the action of two external forces, viz., one of gravity by the load, and one of reaction by the foundation. These forces bring into play equal and opposite forces of resistance, provided that the material is strong enough, and when the material exerts these internal forces it is in what is called a state of stress. The bars in the braced frame (Fig. 9) have been described as being subjected to the action of external forces. They would also be *stressed* because each would, while strong enough, exert an equal and opposite internal force of resistance to combat the action of the external forces. The *intensity of stress* is the amount of stress per unit of area; as 10 tons stress per square inch of area.

21. STRAIN.—When a body of material is acted on by external forces, it is stressed as was pointed out above. This stress, or exertion of resistance, produces an alteration in the shape of the body, and by so doing it is said to *strain* it. The braced frame (Fig. 9) may be again taken as an example. It was shown that the external forces produced stresses in the various bars, which it will now be evident would alter them in a more or less degree, so that they would be *strained*. Strain may be defined as the tendency of stress forces to alter the form or shape of the body in which they act. The nature of the strain on a particular body depends on the relative action of the stress. The "unit strain" is the amount of strain per unit of length; it might be expressed, "the strain is $\frac{1}{100}$ part of a foot," the foot being the unit of length of the body.

22. SHORTENING STRAIN.—When the external forces are compressing, the internal resisting forces act away from each other, and they tend to shorten the body, and crushing may result.

23. Stretching Strain.—If the internal resisting forces act towards each other, as they would in the case of the external forces pulling one from the other, the effect will be to elongate, and possibly pull asunder the body.

24. Shearing Strain.—Stress forces which will tend to cause one portion of a body to part from, and slide over the other portion, produce what is called a *shearing strain.*

A diagram showing the shearing stresses is drawn under each of the examples of loaded beams shown in Fig. 8. As will be seen they are rectangles for cases A, C, and E, while for examples B and D they are triangles. The height of rectangles and altitude of triangles is marked S in each case. The base of each diagram is set out equal to the span of the beam, while the value of S (found by the formula set out on right hand side of each sketch) is set up by some scale of tons or lbs. In the case of a triangular diagram, where the stresses vary from max. to zero, the intermediate ones may be determined by scaling off the length of the perpendicular between the base and side, at the particular point at which it is required. For instance the stress. at A, (sketch B. Fig. 8) will be whatever E F measures by the scale to which the value of S was set up.

25. Twisting Strain occurs where the stress forces act so as to cause one part of the body to turn in an opposite direction to the other part; such for instance, as in the case of two wheels tending to revolve in opposite directions, and both secured or keyed to the same spindle, when there would be a tendency to twist the latter.

26. Cross-breaking Strain is illustrated in the case of a girder supported at both ends, and holding up an imposed weight. The stresses due to the forces—indicated by PQR, Fig. 6—tend to bend and break the girder at O. This kind of strain is really made up of stretching and pushing strains.

27. Indentation Strain.—When two bodies are pressed together by the action of external forces, there is a tendency on the part of one body to press into the other, partly by crushing, and partly by shearing. This is called *indentation strain.*

28. From the foregoing it will be evident that:—

(a) Compressive stress will produce a				Shortening strain.	
(b) Tensional	"	"	"	Stretching	"
(c) Shearing	"	"	"	Shearing	"
(d) Torsional	"	"	"	Twisting	"
(e) Transverse	"	"	"	Cross-breaking or bending	"
(f) Bearing	"	"	"	Indentation	"

29. Ultimate Stress.—The ultimate stress which a body may be subjected to will be its maximum power of resistance to external force, so that when the force is greater than the ultimate stress capability of a body, collapse will take place.

30. Factor of Safety.—In practice it is not possible, with safety, to subject a body to its ultimate stress, and therefore, to make sure of stability, the stress brought into play by a force, is always arranged to be considerably below the ultimate stress. In other words the ultimate stress of a body is divided by some number and the quotient is taken as the *safe stress* that the body may be subjected to. This number or factor of division is called the *factor of safety.* The selection of the most suitable factors of safety is a matter that cannot be dealt with satisfactorily here, on account of the necessarily limited scope of these articles, and the very wide field of debatable points which this important question opens up. The factor of safety to be used will depend on the nature of the building, the kinds of loads, the materials. and last but not least, the class of workmanship. It will therfore be evident that with all these considerations, in addition to economical requirements the question of the proper factors of safety is one that has and is still having a great amount of attention from engineers, and has been productive of a great deal of controversial strife. In ordinary building with good materials and workmanship it will be sufficient for stationary loads to use:—

A factor of safety of 3 for metals
" " 4 " brick and masonry
" " 5 " timber

Where live loads are liable, that is loads such as moving people, vibrating machinery, and wind force, it will be necessary to double the factors. Specially high factors of safety are necessary where the character of the work is such as to make thorough inspection and certainty of compliance with the intention of the designer, a matter of difficulty or impossibility. Again, high factors are requisite where the building is of a very important character, and where failure would mean great loss of life and money. In most of the old world countries, and also in the United States of America, the factors of safety used for structural work must be in accordance with Government regulations, but here in Australia at the present time the engineer, architect, or builder is left to please himself as to what he does in this way. The absence of such necessary control by the authorities of the Australian cities, is to be deplored, for carefully prepared and comprehensive rules would lead to the assurance of safety and would also result in economy of design.

31. Elasticity.—There is no such thing as absolute rigidity, for all materials are composed of numbers of molecules, or atoms, and it is the cohesion of these that results in what may be practically called the homogeneity or mass of the material. Practically these molecules are capable of returning to their original position after being subjected to a strain of pushing or stretching, by a stress within a certain limit. Beyond this limit called (the *Limit of Elasticity*) a *permanent set* or disruption of the atoms will occur, which will increase as the stress is increased and will eventually end in collapse, when the ultimate power of resistance is just exceeded. Within the range of the elastic limit, the strain is proportional to the stress, so that if a bar 2 feet long of elastic material, the cross section of which is one square inch, be stretched $\frac{1}{100}$ of its length by a load of 20lbs, it will be stretched $\frac{2}{100}$ of its length by a load of 40lbs., and so on until the elastic limit be reached; after which the ratio between the stress and strain would cease to be constant. However, in the determination of the co-efficient or modulus of elasticity this proportionality between strain and stress is hypothetically considered to hold good until the body is strained to an amount equal to its original length, that is to say it is assumed that the ratio of strain to stress in a bar will continue constant until the bar has been either stretched or compressed through a length equal to its original length, so that the co-efficient of elasticity of the bar taken above would be 2000lbs.

32. The Co-efficient or Modulus of Elasticity is to any particular stress that may act within the elastic limit in a body, as the original or unstressed length is to the strain produced by that particular stress. If :—

L = length in feet of the body.
l = extension or compression per foot of length due to stress of S.
S = the stress in lbs. per square inch.
E = the modulus or co-efficient of elasticity.

The proportion will be :—

$$E : S :: L : l$$

The value of E for any particular material may be arrived at by subjecting a bar thereof, of one square inch cross section, to a compressive or tensional stress, noting the strain produced thereby, and applying the following formula :—

$$E = S\frac{L}{l}$$

The modulus of elasticity is of great use in structural design. For instance, the strain which will be produced by a stress S in a bar of L length can be found by the formula :—

$$l = S\frac{L}{E}$$

or having the strain it will be possible to ascertain the stress producing it by use of the formula :—

$$S = E\frac{l}{L}$$

33. Neutral Axis.—When a body, such as a beam, is acted on by external forces, so as to bring into play a transverse stress, the strain is such that the upper longitudinal portion is in compression while the lower is in tension. The line of division between compression and tension is called the neutral axis. The dotted line through middle of beam, Fig. 9A, is an example of its position. It may be mentioned that the neutral axis will pass through the centre of gravity of a cross section of any beam, provided that the beam is not stressed beyond the elastic limit.

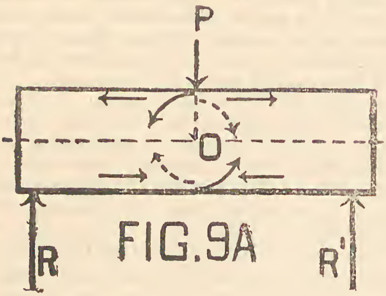


FIG. 9A

34. Bending Moment.—Is the name given to the moment of a force (see article 11 ante) about a point which tends to bend and break the body at that point. The actual point about which bending or breaking occurs in any cross-section, is located in the neutral axis, and in dealing with a girder or beam it may be taken as the fixed point O, see Fig. 9A, about which the bending moment due to external force is taken.

35. Moment of Resistance.—Fig. 9A represents a beam acted on by three external forces P R R' which can be supposed to keep it in equilibrium while the rigidity or strength of it is sufficient to prevent collapse by bending or breaking. Point O is the point on the neutral axis about which bending or breaking of the beam will occur, at which the force P may be therefore taken to act, and which can consequently be taken as the fixed point, around which the forces R and R' tend to turn the left and right hand portions of the beam. Taking the right-hand portion of Fig. 9A. the dark circular arrows show the direction which R' *tends* to turn it around O, and Fig. 9B indicates how the same portion turns round O during collapse. The broken beam is shown with the upper fibres compressed or pushed into, whilst the lower fibres are pulled away or torn from, those of the other or left-hand portion. Allowing then, that the external forces (while maintaining the beam amongst themselves in equilibrium) tend at the same time to bend and break the beam, as set out geometrically by the lines of forces and circular arrows in Fig. 9A, and by the drawing Fig. 9B of the broken beam, it will next be necessary to describe the means of arranging for a sufficient resistance in the beam to combat this tendency to bend and break. That is to say it must be arranged that the moment of resistance of the beam shall equal the bending moment due to the load. The straight arrows, Figs. 9A and 9B, indicate the compressional and tensional stresses acting in the beam. Now a little reflection will make clear that these stress forces tend to turn the portions of the beam in opposite directions to the directions that the external forces would tend to turn them. Again, taking, for the purposes of illustration, the right-hand portion of the beam Fig. 9A, it will be seen that the stress forces of compression and tension tend to turn it round O in a direction which will be opposite to the action of the external forces as is indicated by the dotted circular arrows. Consider Fig. 9C to

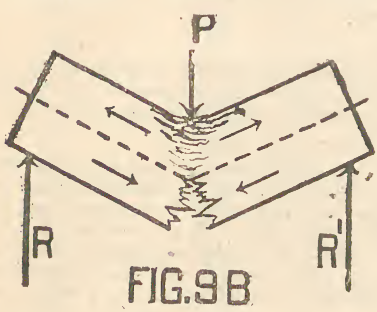


FIG. 9B

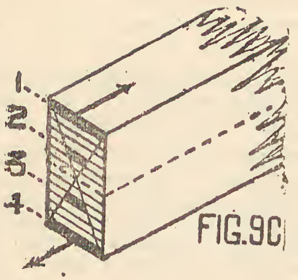


FIG. 9C

be the beam cut at that cross section which contains point O. The section is shown divided by a number of horizontal lines, each two of which contain between them a layer of particles, or fibres, The upper layer marked 1 is composed of fibres in compression. On the other hand the lower layer of fibres marked 4 are subjected to a tensional stress. These stresses of compression and tension are, as far as direction is concerned, indicated by the arrows. Their action is opposite and their forces equal—they will consequently form what is called a *couple*, the moment of which about its axial point (O in this case) is equal to one of the stress forces multiplied by the distance (1 to 4) between them. The moment of the couple of the layers 1 and 4 about O will be the moment of resistance of *these* upper and lower layers against the moment of turning or bending of the beam and the moment of resistance of the other layers (2 and 3 for example) may be found in the same manner. At this stage it must be pointed out that the layers are not all of the same value in stress. That is to say, that as the layers are nearer to the neutral axis their power of resistance decreases, or, putting it a better way, the stress in any layer of fibres is proportional to the distance from the neutral axis. The triangles formed with the top and bottom of the section as bases and lines drawn down to the centre of the section as sides will therefore represent what may be called the effective area of the portions above and below the neutral axis. It will thus be evident that when taking the layer 2, only that portion which lies within the upper triangle, and similarly only that of 3, within the lower triangle may be regarded as effective, and such only of either can be used when calculating the moment of couple. The moment of resistance of the whole beam will be the sum of the moments of the various effective layers of fibres. The general formula embodying this may now be considered :

Let MR = moment of resistance of the beam.

Let r = the safe stress in tons per square inch which the material will bear in compression and tension.

Let b = the breadth in inches of the beam.

Let d = the depth in inches of the beam.

The area of each of the effective triangles of the section of the beam will be $\frac{1}{4}$ b d, and the total resistance of the section, either in compression or tension, r $\frac{1}{4}$ b d. The distance between the centres of gravity of the triangles will be $\frac{2}{3}$ d.

$$\text{Then MR} = r\,\tfrac{1}{4}\,b\,d \times \tfrac{2}{3}\,d = \tfrac{1}{6}\,r\,bd^2.$$

This formula is exact, but only applies so long as the beam is loaded within the elastic limit of the material comprising it. If the materials be stressed beyond the elastic limit the strain produced will not be proportional to the stress, and the neutral axis will not coincide with the centre of the beam. To get over the difficulty the co-efficient of transverse strength, called the modulus of rupture which is obtained by experiment, is used instead of the value r representing the compression or tensional strength. The formula is therefore written as follows, f being the modulus of rupture :—

$$MR = \tfrac{1}{6}\ f\ b\ d^2.$$

In well proportioned steel or wrought iron plate girders the difference between the modulus of rupture and the tensional strength of the material is not of sufficient importance to necessitate consideration and the latter is used. In these girders the webs section is not included in the calculation of the resistance to bending—the flanges alone being taken. The formula generally used is as follows :—

Let r = the safe tensile stress in tons per sqr. in. of the material.

Let a = the area of the top or bottom flange.

Let d = distance between the centres of gravity of the top and bottom flanges.

$$\text{Then MR} = r\ a\ d.$$

CHAPTER III.

SHORING AND UNDER-PINNING.

36. The Operation of Shoring up, or under-pinning a structure, is one that is frequently met with in practice, and it is not by any means among the least important of the many matters, which during building erection, require the exercise of the judgment and skill of the supervising Architect and the builder.

37. The First Matter to be attended to in the case of shoring up or under-pinning a building, is to determine as accurately as possible the forces acting, or which are likely to act, on the part to be shored up or under-pinned. These forces will generally be of gravity by the weight of the walls, floors, roofs, furniture, goods, etc., but sometimes the wind has to be considered.

38. Consideration of the Conditions of Stability of a Wall.—Fig. 10a shows the section of a wall resting on a foundation, which we will suppose is perfectly

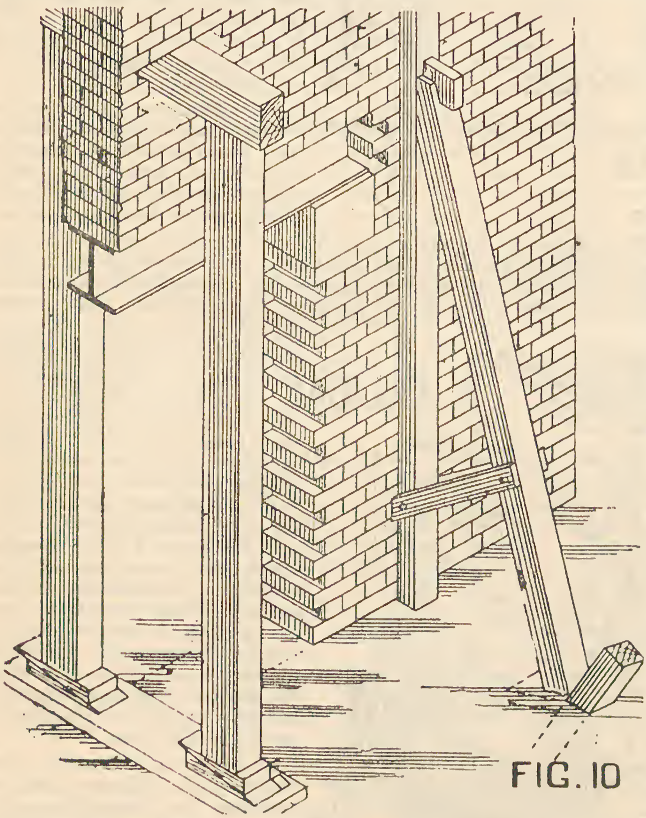


FIG. 10

solid and unyielding. The outward side of the wall is on the right or AB side. Now let it be estimated what is the smallest force that will turn the wall so that it may fall outwards, that is to say, it is required to find the force that will just exceed the power of the wall to maintain its upright position. It can be assumed that the wall will, in the event of fall, turn on the lowest outside point B, so that the first thing to do is to find the moment of the weight of the wall about B. The force of gravity or weight of the wall will pass through the centre of the gravity O, of the wall, and is on the drawing, shown by the line P. This force P would, were it not for the resistance of the foundation, turn the wall in the direction of the arrow about B. Therefore it will be seen that the moment of P about B will be the expression of

the power of the wall to stand up. Let Q be a force acting against the wall and in an outward or contrary direction to that of P. If the moment of Q about B equals the moment of P about B the wall will just stand. An excess of power on the part of Q will, however, result in overturning. It will thus be clear that provision must be made for resisting any outward acting forces which exceed the moment of resistance of the wall. The position of the centre of gravity of the wall to be shored must be considered, for it is to be remembered that for the weight of the wall to be effective in maintaining stability, the centre of gravity must be on the inward side of the turning point (B in the case of Fig. 10a) otherwise the weight of the wall will be a factor in the power of overturning, for then the weight or gravity force will, of course, tend to turn the wall in the other or outward direction. In an upright and properly designed wall, the centre of gravity will be well on the inward side of the turning point, but it is just in these cases which call for help by shoring that will be found nearly in a position to cause collapse. This is the case that is frequently met with when the shoring operations are preparatory for repairs.

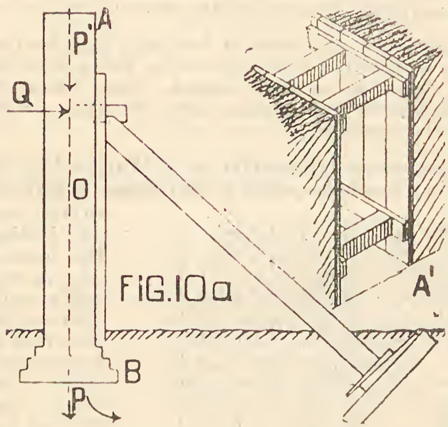


FIG. 10a

39. Raking Shores.—The inclined prop or support shown in Fig. 10a is called a raking-shore. One of these shores is generally allowed for each storey in the building to be shored up, and they are arranged one above the other in groups, which are about 15′ apart—see Figs. 10 and 10A. An upright piece of timber called a *wall piece* is placed against the wall to receive the heads of the shores in each group. Connection between each shore and wall piece should be made by mortising the wall piece and inserting therein a piece of timber called a *needle*, the outward projection of which forms the abutment for the top or head of the shore. Of course care must be exercised that the needle, in any case, is strong enough to resist cross breaking by the upward pressure of the shore. A needle forming the abutment for a shore-head is shown in Fig. 10. The piece of timber against which the bottom ends of the shores abut is called the *sole piece*, and its solid and secure foundation, in every case, is a matter of the greatest importance. Pieces of timber are used crosswise to brace the shores in each group together, and they should be connected to the shores with bolts.

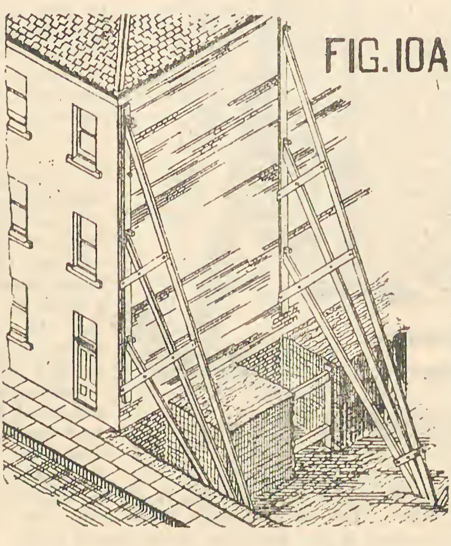


FIG. 10A

40. Sizes of Timbers for Shores.—The following table of scantlings for raking-shores in cases of shoring adjacent but sound buildings against accident during excavation, etc., will be found useful.

TABLE OF SCANTLINGS FOR OREGON PINE RAKING SHORING TIMBERS.

Height of Wall to be Shored.	Cross-section of Raking Shore
15 to 20 feet	6'' X 4''
20 to 30 "	9'' X 4''
30 to 40 "	10', X 5''
40 to 50 "	12'' X 6''
50 to 60 "	12'' X 8''
Angle of inclination about 60°	

41. FLYING SHORE is the name given to a shore which acts horizontally between the two structures to be shored up. For example take two houses, separated by about 30 feet, and between which a new building is to be erected. During the excavation work it will be necessary to shore the two against accident and collapse, and this may be accomplished by arranging the shores, not raking, but horizontally between the two buildings, so that each shore abuts against one as well as the other. For the sake of stiffness and prevention of "sagging" the shores in each group are strutted and braced together, much on the same principle as a roof truss.

42. VERTICAL SHORES are those used to support a wall, or part thereof, independently of foundations during alterations such as making of openings and so on, or while repairs to, or sometimes when new foundations are being built in. A case of common occurrence is that where an opening, for a shop front or some such purpose, is to be made in an existing wall. An example of this case is shown by Fig. 10. The space above where the opening is to be, is first made secure against collapse by being temporarily supported or under-pinned by small " small beams" or "needles" which are themselves supported by strong upright timbers or columns. A " needle," with its two supporting uprights, one inside and the other outside, the wall is shown in the illustration Fig. 10 A longitudinal opening is then made, and either the permanent supporting arch or girder, as the case may be, inserted. The wall above the arch or girder is then made good, so that the weight of the upper part of the wall may be considered as fully resting on the arch or girder and permanently supported. To be successful it will be necessary to see that the making good above the arch or girder is solid and tight, and that the arch is firmly supported at the skewback, or that the girder, if such be used, is securely bedded at the bearings. In the example illustrated a *template* stone is provided for the bearing of the girder which forms the permanent support. The next step will be to make the desired opening in the wall by removing that portion which is between the supports of the arch or girder and making good the jambs. The illustration shows the girder just put in, the filling in of wall above completed, and the opening made underneath.

43. UNDER-PINNING is the term applied to the process of building new supports or foundations in under the piers or walls of an existing building. When the excavations for the basement of a building to be erected will descend to a level below that of the bearing of the footings of an adjacent building, right up against which it is intended to build, it becomes necessary, unless the nature of the foundation be of an unyielding character such as rock, to ensure the safety of the existing structure by building in under its footings a foundation wall which will reach down to the level of the foundations of the new building. The necessity for so doing will be obvious, for if the excavations were carried right up to the boundary, the material (if it be clay or such like) composing the building site will crumble and fall in, causing collapse of the building wall resting on it. The troublesome and exceedingly hazardous work of under-pinning may be accomplished by proceeding as described in the following article provided that the natural foundation is of a fairly stiff and reliable character.

44. UNDER-PINNING OF A WALL rendered necessary by excavation for basement of new building. The excavation for the basement is commenced in the middle of the site, and carried down to the desired level and towards the adjoining building until within about 12ft. thereof, so that a strip of land of that width is left completely along the foundation (see Fig. 10A). Twelve feet as the width of such a strip is mentioned, but, of course, circumstances will alter the allowance such as, for instance, where the building is very high, or where the natural forma-

tion of the site has a tendency to be soft, the strip left must be much wider than if the natural foundation is good, or the building comparatively low. In any case it will be necessary to have plenty of allowance on the side of safety. The side wall of the adjacent building is then well propped up with raking shores.

A small cutting is next made through the strip of sustaining earth at right angles to, and running in under the foundation of wall, and in the opening so made is built a vertical strip of new foundation wall, the joint of top of which with bottom of existing wall is packed tight, so as to ensure a full and secure bearing. Another cutting is made some distance ahead and another strip of foundation wall built in the same manner, and so on at intervals until the whole of the wall rests securely on vertical sections of the under-pinning. The intervening masses of earth are then removed, and the vertical strips connected with walling of similar character. The under-pinning is generally executed in brick-work, which requires that great care shall be taken to have the course in the various strips, on the same level, and the bond properly set out in each, so that when the intervening spaces are built in, there shall be perfect continuity of the *courses* and *bond*.

Under-pinning should always be built in Portland Cement mortar, and the building of it should not be too fast, so that the settlement, whatever there may be, in itself, may take place prior to the imposition of the weight of the wall. Figure 10A is illustrative of the process of under-pinning just described.

45. Under-pinning in Natural Foundations.—In the event of the material of the site being sand or some such material of little lateral stiffness it will be impossible to commence excavating the site before the completion of the work of under-pinning. After first shoring up the wall the next thing to do will be to sink a vertical shaft to the level of the proposed bottom of the new foundation wall. Working in this shaft, it will be possible to excavate a space under the wall, and so make room for the building in, of a vertical strip of or section of the new foundation wall. Similar shafts are then sunk at intervals along the wall, but it will be noted that a fresh shaft is not commenced until the strip is built in, and packed up from the last one. The strips are connected by removing the intervening material, and building in the intervening lengths of wall. Of course the material at the sides of the shafts will have a tendency to fall in, and the methods of preventing this as applied to all such cases will be described in the next article.

40. The Shoring or Timbering of Excavations, Such as Shafts, Trenches and Cuttings.—To prevent the earth, forming the sides of a trench or shaft, from falling in, it is necessary to temporarily retain by placing against them, upright or horizontal timbers, called *polling* or *sheeting boards*, which are kept in position by horizontal cross struts, from one side to the other. The polling boards are generally placed horizontally, but it is sometimes convenient to have them vertically. The side of one of the cuttings, Fig. 10A, is shown (with a view of affording an example) as shored up with two vertical polling boards, and cross struts. In very loose material it is necessary to have the sheeting or polling boards placed quite close together, in which case it is usual to have longitudinal ledge timbers or *waling pieces* crossing them, and against which the struts will act. An example of sheeting with waling pieces and struts is shown at A′, Fig. 10a.

CHAPTER IV.

FOUNDATIONS.

47. EXAMINATION OF BUILDING SITE.—The examination of the Building Site is very important, for the stability of all that may be erected thereupon, depends with a vital import on the knowledge possessed concerning the material forming the site, and the judgment and wisdom displayed in the arrangement of the foundation. The Builder will need not to seek far, for examples of heart breaking failures, due to faulty foundations; and indeed long is the list of Engineering and Building troubles, presented as a warning, that unless care is exercised, difficulties in this direction are very likely to occur. It is therefore at the start absolutely necessary to ascertain the nature of the material forming the site on which the building is to stand, and not only that, but the surrounding conditions likely to interfere with the material, are also to be investigated and allowed for. In districts where the character of the underlying material is well known, and where building has been carried on for a long time, experience will have established ample data to work upon, when arranging for the foundation of an ordinary building; but should the building be of an extraordinary weight, even in such places, special examination is advised. On the other hand in new districts, with nothing to guide in the way of experience, such as is often the case in Australia, the Builder must perforce make the examination, be it ordinary or other building.

48. METHOD OF EXAMINATION.—The most satisfactory method is to sink bores, or deep perpendicular holes, at intervals all over the site. By this means a full knowledge of the character and arrangement of the materials comprising the site will be obtained, and any expense incurred in this way, will be amply counterbalanced by the removal of all risk to the building arising from ignorance of the building site.

49. CLASSIFICATION OF NATURAL FOUNDATIONS.—The materials forming building sites may be divided into 4 classes as follows :—

1.—Unyielding.

2—Unyielding except under certain conditions, such as sand, and gravel, when subject to the action of water.

3.—Yielding as for instance soft clay, silt, and swampy, or marshy ground.

4.—Partly yielding and partly unyielding.

CLASS I.—UNYIELDING NATURAL FOUNDATIONS.

50. SOLID ROCK —The deep and solid rock formations, are to be placed under the head of unyielding, or incompressible natural foundations, and of course offer the best possible conditions for building upon, requiring nothing more than levelling off the inequalities to receive the footings of the building. It may be mentioned, that it is not usual to put on the rock more than one-tenth of its ultimate crushing strength per square foot.

51. ROCK IN BOULDER FORMATION.—If however, the rock is not of a solid and compact nature the case is altogether altered, for oftentimes a comparatively sound stratum of rock will be found deficient in thickness, and underlain by a more or less rotten seam, incapable of bearing weight. Again the rock sometimes occurs in the shape of large blocks or boulders, with a soft or decomposed material surrounding them and filling the interstices. This description of rock occurrence is a most treacherous kind of foundation, on account of the probability of settlement or dislocation of the boulders, which may be brought about, either by the inability of the soft material to bear increase of weight, or by its being removed

through the action of subterranean water. In the case of a heavy building it will be necessary to excavate through such a formation to a solid stratum, as was recently done when preparing for the erection of an important Sydney (N.S.W.) building.

52. HARD SHALE —Hard shale makes an excellent foundation, provided it is not subjected to atmospheric influence, for on exposure it rapidly disintegrates, and is reduced to a powder. In the event of the shale being naturally exposed, care should be taken to have the portion supporting the footings of the building, sufficiently covered with earth, stone, or other convenient covering.

53. HARD CLAY.—Hard dry compact clay is practically unyielding, and is a good safe foundation especially if intermixed with gravel, but the footings of the building should be carried down sufficiently far into it, for the upper part of the clay to a depth of five or six feet is liable to severe changes due to atmospheric influence. Expansion and contraction occur to such a degree, that buildings resting on the upper portion of the clay have been cracked distorted and rendered unsafe. In some of the districts subject to drought cracks from $1\frac{1}{2}''$ to $2''$ wide appear during the dry period. It is usual in buildings of no great weight, where cost prevents sinking very deep, to lay a bed of sand about 4 or 5 inches thick, in the trenches before the laying of the footings, so that any movement due to expansion or contraction is prevented, by the cushion afforded by the sand, from affecting the building.

54. CLAY ON SIDE OF A HILL.—Where a clay foundation occurs on a side of a hill, it will be necessary to inspect that portion of the slope below the proposed building. Should cuttings or drains exist, allowance is to be made for probable slipping of the clay caused by the falling in of the sides of the cuttings or drains. Accidents to buildings have happened where the cutting has been a considerable distance below, and with a view of providing against such a failure the footings must be very much deeper than in the case of a flat site.

CLASS II —UNYIELDING, UNLESS UNDER CERTAIN CONDITIONS.

55. A COMPACT SAND GRAVEL,—is unyielding when protected from the action of water, and makes a very good foundation *Loose Gravel*, may be prepared for bearing the weight of the building, by being saturated or grouted with thin cement grout.

56. DRY SAND.—Dry sand is one of the best weight resisting materials for a foundation, but is rendered quite useless by the presence of water, and also unless it is laterally confined, it spreads when subjected to weight. Where the surface is level for some distance round the building, and also free from effects of flood or other water, sand will be found to answer well, but on the side of a hill, or in any place where it can slip or spread out, or where subjected to the action of running water, the portion under the building should be confined or retained, by sheet piling. When piles are driven close together, in a line, the arrangement is called "sheet piling," and is the method adopted to confine sand and other loose materials. The piles are driven between guide piles, and longitudinal pieces called "waling pieces." The foot of each pile is cut or bevelled as indicated by Fig 11, with a long and short bevel, and is placed as is also shown by Fig. 11, so that during the driving process a tendency towards the last driven pile is caused. By this means the piles are brought close together.

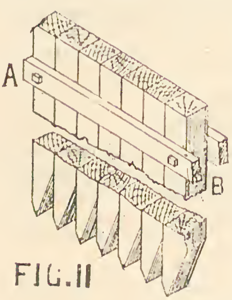


FIG. 11

CLASS III.—YIELDING NATURAL FOUNDATIONS.

57. ORDINARY CLAY is capable of bearing a very fair weight without serious compression, but, as in the case of the hard clay before mentioned, it will be necessary to excavate to a depth free from the effects of weather change.

58. SOFT AND POROUS CLAYS.—Pure soft or porous clays and soft loamy earths go to form the medium class under the head of yielding materials, for though not so good as ordinary dry clay and solid hard earth, they are very much better than

quicksand or mud. The methods of dealing with these materials are, however, much the same as for silt, quicksand, and mud ; the only difference in their favour being that should access to a better substratum be impossible, it will generally be feasible to spread the weight to a safe load by using wide footings, whereas in a swampy or silty ground the use of piles is almost unavoidable.

59. Silt, Mud, and Quicksand —Silt or quicksand, and swampy soils, are the most unreliable and treacherous materials that can be met with for building upon ; and, unfortunately, such materials often occur, for in cities convenience requires that the large stores and manufactories should be erected along, or as near as possible to, river frontages or harbour shores, and it is in such places that mud and silt is most likely to be found The weight-bearing power of these semi-fluid deposits is very small, and is very much of the same character as that afforded by water when supporting a floating body. However as bad as may be the foundation afforded, examples are offered where heavy buildings have been safely founded on quicksand, or mud deposits, but safety has only been provided for by very skilful spreading of the weight on footings with an area so large as to amply demonstrate that bearing space was not a matter of condideration.

Class IV. —Sites Composed of Unyielding and Yielding Materials.

60. So far only cases of sites composed wholly of either *unyielding, unyielding under certain conditions*, or *yielding* have been dealt with, but it is to be pointed out that cases frequently occur where one part of the site is unyielding and the other yielding, such as a water frontage which may have silt and mud of considerable depth over a great portion of the end near the water and the remaining part may be solid rock ; and so on. To erect a building partly on unyielding and partly on yielding beds would be sure to produce disaster, for it is to be remembered *that it is not so necessary that the bed on which the building rests shall be unyielding as that it shall be absolutely uniform in its weight-bearing power.* It will be therefore most important that the softer materials be excavated, and all the footings founded on material of the same character. Should the drop or fall of the strongest material be very great, the part of the building over the soft portions of the site may be supported on piers reaching to the level of the hard material.

61. Determination of Weight-bearing Power of Natural Foundations—Footings and Improvement of Yielding Foundations —With the unyielding natural foundations there will be no difficulty whatever in the matter of arranging the area of the lower parts of the footings, because unless the imposed building be of a most extraordinary weight, the bearing power of this class of foundations is never nearly reached. The various precautions, noted during their description, need only be taken. It is with foundations of the yielding class that the real difficulties are met with, and to be successful requires the exercise of the greatest skill and care. Being compressible in a more or less degree, it will be necessary to determine the safe load for the particular kind of formation.

62. Estimation of Bearing Power.—The following formula from Rankine's "Civil Engineering" will serve to determing the depth that must be sunk into, and safe pressure that may be put upon, quicksand, soft clays, and alluvial soils :—

W = weight of a unit volume of the soil, quicksand or clay.
h = depth to which the footings are to be sunk.
A = the angle of repose of the soil, quicksand or clay.

then $Wh\left(\dfrac{1 + \sin A}{1 - \sin A}\right)^2$ per unit of area.

An application of the above is as follows :—

W = 100lbs. per cubic ft. for soil
h = 5ft. as depth of footings into the soil
A = say 15°

Consult any tables of sines for sine 15°. It will be found to be ·25882.

$$\text{then } 100\text{ft.} \times 5\text{ft.}\left(\frac{1 + \cdot25882}{1 - \cdot25882}\right)^2 = 100 \times 5\text{ft.} \times 2{\cdot}9 \text{ lbs.}$$
$$= 1450\text{lbs. pressure per sq. ft.}$$

63. Angle of Repose.—The angle of repose is the inclination of the slope at which the material will naturally settle. It can be very easily determined by making a heap, sufficiently large, of the particular material, and measuring the inclination of the slope or batter of the heap.

64. Advisability of Deep Excavations for Footings.—It will be seen from an inspection of the formula that the depth to which the footings are sunk is a consideration. and this will be evident, for the silt (or mud) being in a semi-fluid state its tendency is to spread immediately on the imposition of a load, but such spreading is not so likely to occur when the load is applied at a level at some depth into it, because the silt under the load is kept in its place by the lateral resistance of the surrounding silt. Therefore the greater the depth, the greater will be the weight of that surrounding. Again, the angle of repose is also a factor, because the greater the angle the less will be the tendency to spread, and hence clay will have a greater supporting power than quicksand.

65. The table here given will be found of value when designing the bearing area of footings.

TABLE I.

Showing Safe Bearing Power of Materials usually met with for building upon.

Material.	Remarks.	Safe Bearing Power in Tons per sq. ft.
Rock		One Tenth of the Crushing Strength.
Gravel	Compact and Sound in Deep Strata ...	8
Gravel	Fairly Loose	3
Sand	Compact and free from water and not liable to slip	6
Sand	Ordinary but free from water and not liable to slip	4
Shale or Clay ..	Dry, and in deep strata, hard ...	4
Clay	Fairly dry and hard	1·5
Clay	Ordinary, but liable to be wet ...	1
Alluvial and earthy or poor clayey soils.		·5

66. Design of Footings.—Having determined the safe pressure per square foot, the next step will be to make the bottoms of the footings of area sufficiently large to transmit the load so as not to exceed such safe pressure. An example will, perhaps, more fully explain what is intended to be conveyed by the foregoing :—

A pier, together with the load on it, weighs 10 tons.

The material of which the building site is composed will safely bear, say 2 tons per square foot.

$$\left.\begin{matrix}\dfrac{10}{2} & \begin{matrix}\text{weight of pier and load on it}\\ \text{tons safe load per sq. foot}\end{matrix}\end{matrix}\right\} = 5$$

So that the area of the footing of the pier shall not be less than 5 sq. feet.

Of course the total weight of the building must be accurately arrived at, and also the exact amount thereof borne by the lower parts of the various walls and piers, so that the area of the footings may be proportionate. A pier in the same

building, as the one in the above example. with a load (including its own weight) of 6 tons, to be in proportion, its footing area would be 3 sq. feet.

Suppose, for instance, it were otherwise, and that it had footing of the same area as the pier with 10 ton load, the soil would be unequally loaded, and unequal settlement would take place, and cracks occur in the building as a consequence. It will therefore be evident that as well as having an uniformly weight-resisting natural foundation, it is also *just as necessary to provide for all footings being in proportion to the weight borne.* Settlement is not so much to be feared as that one portion shall settle more than another.

67. Proportion of Footings.—Fig. 12 illustrates a mode of failure, where the areas of the footings are not properly proportioned.

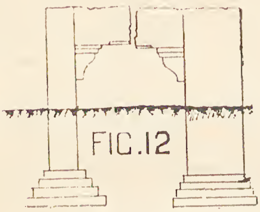


FIG.12

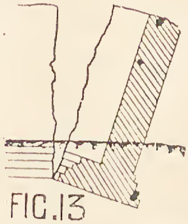


FIG.13

68. Centre of Pressure.—The centre of pressure of the wall or pier should be over the centre of bearing of the footing area. Fig. 13 shows a failure owing to the wall being built on one side of the footing.

69. Weight of Building.—The total weight. and the method adopted to find the exact portions of it borne by the lower walls and piers of a building, will be more conveniently dealt with when describing arch and girder design later on.

70. Concrete Footings.—In the event of the weight being not too great to allow of a reasonable area of footing, the best method to adopt is to lay a bed of concrete in the trench. The area of the bottom of the concrete to be proportioned to distribute the load safely, and the thickness to be great enough to prevent transverse breaking. Concrete is spoken of as being the best in such cases, because not only is it very strong in itself, but, if properly laid, the whole bed becomes one mass, or piece, and consequently distributes better than stone or brickwork. (See article hereinafter for Composition of Concrete).

71. Spreading Courses.—The portion of the wall next above the Concrete should be spread out in "*stepping*," or "*offset*," courses to provide for the proper distribution of the weight over the concrete. (See Fig. 14, which indicates the

FIG.14

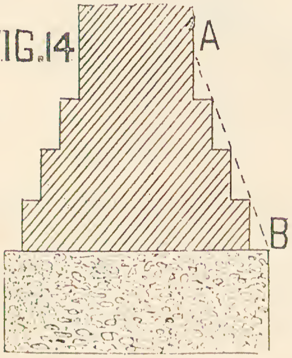
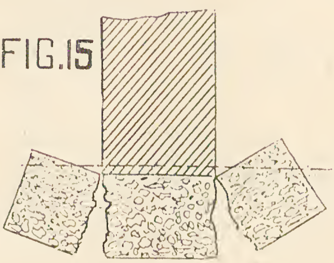


FIG.15



proper method). The greater the inclination made by the line AB, the more stable will be the work, and the inclination of AB will be increased as the projection of

each offset is lessened. Fig. 15 shows a wall built without offset courses on the concrete, together with the mode of probable failure.

72. Masonry or Brick Footings.—When for various reasons, such as cost, etc, it is found not possible to use concrete, the footings may be of masonry, or brick-in-cement, but the same precaution as to spreading, noted in last article, must be taken. However, masonry or brick footings, are never as efficient, for it is not possible to obtain the compactness and homogeneity throughout the whole mass, as in the case of concrete.

73. Iron Hoop in Brick-in-Cement Footings.—The value of brick-in-cement for footings is greatly enhanced, if lengths of galvanized iron hoop of stout gauge, be built in between the courses.

74. Steel Rail or Beam Footings.—Of late years the American Architectural Engineers have developed a new method of securing a very large amount of bearing area, with a very small thickness of footing. By reference to Fig. 14, and remarks already made concerning the inclination of A.B., it will be evident that with concrete or masonry footings, the greater the area, the greater will be the number of off-set or spread courses and consequently the greater the height or thickness of the footings. At Chicago, U.S.A, perhaps more than at other places has the question of building foundation been fully considered, and with the unusual conditions existing, it is not surprising that the matter has had extraordinary attention. With buildings so tall as to be famous, and a natural foundation of very small weight-bearing power, necessity arose for either footings of great area or piles. The serious disadvantages connected with the driving of piles (to be touched on hereafter) caused a tendency to use footings, but the massive and clumsy system of spreading masonry, or concrete, was departed from, and the necessary stiffness and strength gained with a comparatively small thickness, by using steel rails, or I

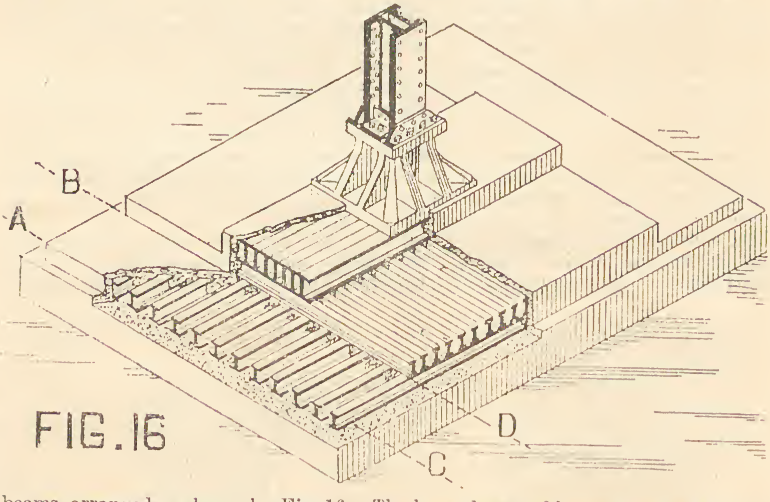


FIG. 16

beams, arranged as shown by Fig. 16. The lower layer of beams rests on a bed of concrete, and the spaces between the beams are also filled up with concrete. The beams should be well coated with paint, or tar, prior to laying. The sketch, Fig. 16, shows the arrangement of a steel beam foundation for supporting a wrought iron column with cast iron base. The design of such footings against failure, is governed by precisely the same conditions as in the case of masonry or brickwork offset courses, and the projection of each layer beyond the one next above, must be considered as a cantilever uniformly loaded by the re-action of the pressure due to the portion of the load which it distributes. If not properly designed each projecting layer would break as would the badly proportioned footing shown by Fig. 15. The bottom layer may be taken as an example. Let the load of the column together with the weight of the upper layers, be 1,056,000lbs., and the area of the

lowest layer 16′ x 22′=352 square feet. Then 1,056,000lbs. ÷ 352 square feet = 3000lbs., which would be the pressure per square foot, exerted by the lower layer on the clay. The lower layer projects 4′ on each side of the layer next above hence the area of each projection is 16′x4′×64 square feet. It will therefore be clear that, of the total pressure exerted by the bottom layer, the projections thereof take each 192,000lbs. The projection of the lower layer marked A B C D, on the drawing, Fig. 16, would therefore be calculated as a cantilever with uniformly distributed load of 192,000lbs. pushing upwards and tending to break it along the line B D. The method of finding the bending moment of such a cantilever will be explained under the head of girder design. Each of the layers must be taken in the same manner, with the column load and the weight of the layers, or layer above (the top layer will have only the weight of the column load), and the re-action found for each projection. It is of course to be noted, that the intensity of pressure or weight per square foot, *increases* as the area of layer *decreases*, so that the top layer will exert greater pressure per square foot than will the lowest layer. Steel beam footings may be used with advantage on all compressible soils, and their more extended use is probable.

75. PILE FOUNDATIONS.—With soft clay or mud soils and quicksands, it very often happens that it is not practically possible to obtain sufficient footing area to spread the weight, and in such cases it becomes necessary to resort to piles. Bearing piles, as they are called, are long pieces of timber (generally circular in cross section) driven vertically into the soil.

76. METHOD OF DRIVING PILES.—They are usually driven by blows from a falling weight called a "*ram*" or "*monkey*." Figure 17 shows the general form of the machine, by which the ram is raised and let fall on to the head of the pile. After each fall, the ram is raised, either by hand power applied to a crab winch at the feet of the "*leaders*," or by steam power, and when raised to a sufficient height, a sudden release from the perpendicular rope, is effected by means of the claw lever shown in the sketch. The two upright pieces which guide the ram in its descent are called "*leaders*," and the ram itself is usually a block of cast iron. As will be seen by Fig. 17 the ram is provided with a tongue or projecting piece E, which fits between the "*leaders*," while the plate B., bolted to the tongue, prevents the ram from getting away as it descends. The height of the fall of the ram in these machines may be anything up to, but should not (for reasons to be given hereafter) be more than thirty feet. The weight of the ram varies from 500 up to 3,500 pounds. Experience has served to show that a light ram with a high fall has a greater tendency to compress and split a pile than a heavy ram with a lowfall. Again with a heavy ram and lowfall, the blows may be delivered very rapidly, and this is an important matter, for it has been observed that if a pile be driven to a certain depth, and allowed to remain for some time undisturbed, and then again struck with the same ram with same fall the penetration will not be as great. This is explained as follows :—

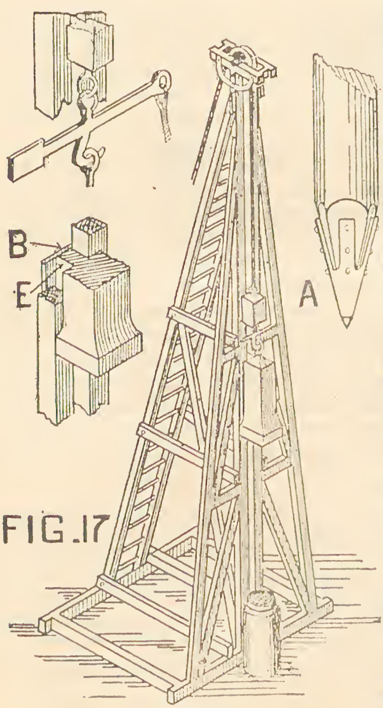


FIG. 17

(a.) During the penetration of the pile, due to the blow, the soil is greatly disturbed.

(b.) The less the interval between the blow, the less chance will the soil have to re-arrange itself or (as it is called) " harden."

(c.) It must, therefore, be evident that the more the soil "hardens," the greater will be the resistance to the further penetration of the pile, so that the machine which delivers its blows with the greatest rapidity will be the most successful in driving the pile into the soil.

The rapid driving of the pile is consequently to be desired, for thereby all the advantages of the increased resistance from "hardening" which will then take place only at the completion of the driving, is gained for the support of the load. The engineers of the Harbours and Rivers Department of New South Wales, specify that the ram shall be 2240 lbs. with a fall of 10 feet.

77. Steam Pile Driver.—Nasmith's steam pile driver is a machine, the action of which is very similar to the well-known steam hammer. The ram is attached directly to the piston rod, and the whole machine rests upon, and is secured, to the head of the pile. It is very effective in its operation, for it delivers with great rapidity, blows, from a heavy ram (about 3,500 lbs.), through a very small fall (three feet) and in works of an extensive character its use is attended with great economy.

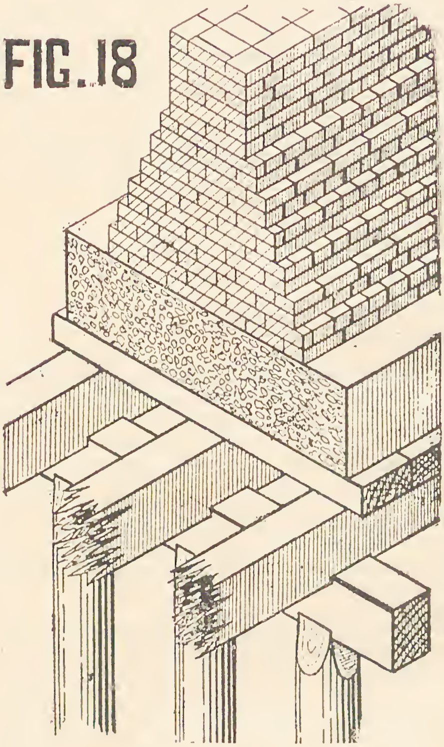
78 Timber for Piles.—A pile should be composed of hard durable timber free from knots, and should be capable of being obtained in long lengths. The various Australian Hardwoods possess these qualifications, but Iron-bark and Turpentine may be mentioned as being especially suitable. Iron-bark is the best of the hard-woods, and is capable of great resistance to compression. Turpentine on the other hand, while not being quite as strong, is yet, as far as resistance to decay is concerned, if anything, superior to Iron-bark. Experience has also shown that it is the least liable to the attack of marine borers, such as the teredo. These desirable properties are due to an oleo-resinous layer, about $\frac{1}{4}$ inch thick, between the bark and timber, and of course if advantage is to be taken of it, the pile must be driven (as recommended by Mr. Maiden, F.L.S., Consulting Botanist to the New South Wales Government) with the bark intact. There is also another colonial timber, viz., Brown Pine, which is strongly recommended for piles, on account of its general immunity from the depredations of the white ant and teredo. Good qualities of these timbers, when buried underground, will remain durable and sound for a practically unlimited time provided that uniform conditions of soil are existing. A timber cannot last in a soil that is liable to be dry at one time and wet at another, for there is nothing so destructive to timber as the alternative action of dry and wet. For this reason the tops of the piles should be as much below the surface of the soil as possible.

79. Pointing of Piles.—The lower ends of the piles are pointed to facilitate penetration when driving ; and when hard strata is to be passed through, the points should be shod with wrought iron shoes, as shown by Figure 17. Where the soil is soft (and this is of course usually the case) the iron shoe is quite unnecessary. The point should not be made too sharp, in any case, for it must be remembered that the point only tends to penetration, and beyond the requirements for driving, this is not needed. A suitable point is shown at A, Figure 17.

80. Collars for Tops of Piles.—Wrought iron collars should be fixed (during driving) to the pile heads, to prevent "brooming" and splitting.

81. DISTANCE APART OF PILES.—2 feet 6 inches centre to centre is the nearest distance apart, that piles may be driven with good results.

FIG. 18



82. PLATFORM ON PILES TO RECEIVE FOOTINGS.—After the piles have been driven, the heads are sawn off, to a uniform level, and a platform of strong timber is built thereon. Figure 18 shows the arrangement of the platform, and also the footings as built on it. A very commendable practice is to excavate round the heads of the piles for some depth, and fill in with tightly rammed concrete.

83. RESISTANCE TO CRUSHING.—All the timbers in the platform should be capable of resisting crushing from the load of the building.

84. DETERMINATION OF BEARING POWER OF PILES.—Bearing Piles may be driven, through a bad stratum, to an incompressible material, in which case they simply act as long supporting columns, and transmit the load on them to the safe unyielding stratum. Or they may be driven into a deep yielding soil, until the friction against the sides becomes sufficient to practically prevent further driving, hence the load on them must be considered as being borne only by the frictional resistance. It will therefore be clear, that in the latter case, a great amount of judgment is necessary, in the determination of the safe load that may be imposed, whereas in the former instance the piles being only long columns the estimation of the load depends on clear and well defined conditions.

85. PILES IN YIELDING SOIL.—The consideration of the bearing pile in yielding soil may be dealt with first :—

- W = the weight of ram.
- h = height of fall.
- x = the depth the pile is driven by the last blow.
- p = the greatest staticial load the pile will bear without sinking further.
- S = the area of average section of the pile.
- L = the length of the pile.
- E = the modu es of elasticity of the material of pile.

Then W h = the energy and power accumulated by the ram at the end of its fall : and the distribution of this energy is as follows :—

(a) In overcoming the friction, against vertical guides of pile-driving machine, and against the air.
(b) In compressing the material composing the ram.
(c) In compressing the material composing the pile.
(d) In driving the pile against the resistance of the soil.

It is difficult to calculate, with accuracy, the loss due to friction against guides, and air ; and for this reason, consideration of this portion of Wh, is not included

in the formulas in general use. However, the loss is not great, provided that the guides and gear of the ram be in good condition, and it will be easily seen that the less the fall of the ram the less will be the friction both against guides, and and air, and the more nearly correct will be the result given by the formula. The amount given out in compressing the material of the ram is very small, and its effect is generelly neglected. Professor Baker has, however, in his "Masonry Construction," included a formula which gives consideration to this loss The

following formula by Professor Rankine is among the best of the many in use :—

$$\frac{P^2L}{4ES} = \text{Portion of Wh spent in compressing the material of the pile.}$$

Px = Portion of Wh spent in driving the pile.

$$\text{Then } Wh = \frac{P^2L}{4ES} + Px$$

Which, when solved, gives

$$P = \sqrt{\frac{4ESWh}{L} + \frac{4E^2S^2x^2}{L^2}} - \frac{2ESx}{L}$$

An experimental pile of carefully judged length, and diameter, should be driven with a suitable ram, and fall, into the soil composing the site, and the last fall of ram, and last pile penetration carefully noted. The foregoing formula should then be applied and the ultimate bearing power of the pile determined. The safe bearing power may then be arrived at by dividing the ultimate bearing power by a factor of safety, which may be any number from 3 to 10, according to the importance of the case. Should the building be of an important character, it will be well worth the cost to impose an experimental load on the pile, and thereby put beyond question the ultimate bearing power. Having found what one pile will safely carry, it will be an easy matter to calculate the number that will be required under each footing. Care must be exercised that all piles are driven to at least the same resistance as the trial one.

86. Piles as Long Columns.—Long columns usually fail by bending under the weight imposed, but in the case of piles, this is counteracted or prevented by the lateral support afforded by the soil through which they are driven. This lateral support of course depends upon the stiffness of the soil, but (except in the case of very liquid soils) is generally sufficient to prevent bending. So that the supporting power will depend on the strength of the timber composing the piles. Therefore to find the safe bearing power it will be necessary to divide the ultimate compressive resistance of the pile by a factor of safety which is usually taken as either 3 or 4. With piles driven through very liquid soils it will be necessary to estimate them as long columns without lateral support. The method of doing this will be explained later on in the chapter dealing with columns.

87. Screw Piles.—Timber piles have been dealt with at some length, because it is thought that the use of these will be found to meet all requirements of the builder, more especially as, in Australia, there is to be obtained in abundance such eminently suitable timber. There are, however, many different kinds of piles, such as wrought iron, and cast iron, in different forms, screw piles, and so on, but these are mostly of service only to the engineer in his more varied needs in this direction. Screw piles, so called because the lower, or penetrating end, consists of a screw or worm, may be noticed, for by reason of it being possible to get them into the soil without hammering them they are of great use where the shaking or "jarring" of the usual driving process may be avoided. Screw piles are either wholly of iron, or are made with the lower end only of iron and a timber shaft. They are screwed into the soil by means of a long lever attached to the upper end. The determination of their bearing power is best arrived at by screwing in a pile and experimentally loading it.

88. Sand Piles.—A very useful method of improving the bearing power of a poor, earthy or clayey soil, is that of drilling vertical holes, or bores, and filling them up with tighly rammed sand. Such are called sand piles, and

there is no doubt that if properly executed they are just as good as if timber piles were used.

89. Disadvantages of Piles.—Some notice must be taken of the disadvantage which attends the use of piles for foundations in certain situations. The "jarring," or shaking effects, due to the driving process, causes in the case of water-holding soils, a ready tendency to "jellify," and thus seriously reduce the bearing power of that adjacent. Again, with a clayey soil, if the piles be driven close together, a liability of upheaval of the surrounding clay is caused. It will, in consequence, be at once evident that where the site of the building is (as is most likely to be the case in a city) surrounded by existing buildings, extreme caution is necessary. A building in Chicago (United States America) settled six inches during the driving of foundation piles in an adjacent site. Screw piles would be the best kind to use in such cases.

CHAPTER V.

LIME AND CEMENT.

90. LIME.—Lime for building purposes is obtained by burning, or more properly speaking, calcining limestone. By the process of calcination, the carbonic acid and water are expelled, and quick or anhydrous lime results. Re-absorbtion of water is called slaking, and this action is attended in varying degrees, according to the nature of the lime, with a reduction to a powder, and a considerable increase in volume. Setting, is the term applied to the hardening of the slaked lime, after being mixed into a paste with water.

91. KINDS OF LIME.—There is a great difference in the various kinds of lime, and the degrees of, and conditions surrounding their setting or indurative powers. For the purposes of distinction a division into three classes may be made as follows :—

(a) Rich or pure lime.
(b) Poor lime.
(c) Hydraulic lime.

92. RICH LIME.—Rich or pure lime is obtained from limestone of nearly pure carbonate of lime (such for instance as white marble and chalk) and is of a very quick or caustic nature, and, during slaking, heat is given out, and the process is accompanied with plenty of noise and vapour. The slaked lime, if mixed to a paste and subjected to the action of the air, will set, or, in other words, will be reconverted to a carbonate by the re-absorbtion of carbonic acid. This class of lime does not possess very great indurative power, and whatever there is of setting will take place only in the air, for it is soluble in water. Consequently it is utterly useless in subaqueous and subterranean work. Much of the lime used in the Australian colonies for building purposes is of the rich kind, and hence it is that the mortar made from it never sets hard. Rich lime shrinks very much during setting.

93. POOR LIME.—Poor lime is that kind which contains about 60 per cent. of pure lime and the balance of silica, in the form of sand, mechanically mixed together. The silica in this inert form has no influence on the setting power of the pure lime, and hence while reducing or making poorer the rich lime does not in any way improve it. It will thus be evident that while it is not so quick, slakes slowly, and is not so soluble on account of the presence of sand, it is at the same time no better suited for moist or damp or important works than the rich lime.

94. HYDRAULIC LIME—Hydraulic lime is that kind which possesses the power of setting when in water or away from the action of the air. This characteristic of hydraulicity is resultant on the combination, during the burning process of silica with some of the quick lime, forming what is known as silicate of lime which when hydrated forms a hard body insoluble in water. This kind of lime is obtained by calcining limestone which contains clay (hydrated silicate of alumina) in varying proportions of from 10 to 30 per cent. As was mentioned in the last article (art. 93) silica when present in limestone in the form of sand or flint is useless, for it is quite inert and will not combine with the lime. Clay, however, contains silica in a soluble and useful form in combination with the alumina ; and during the calcination of limestone containing clay the silica therefrom combines with a portion of the lime (after the carbonic acid and water have been expelled) and forms silicate of lime. . As the temperature is increased to a high degree, the alumina also enters to some extent into the combination and a double silicate is formed The proportion of clay present in the limestone, and the degree of temperature

during calcination, have an important influence on the character of the hydraulic lime produced. When there is a large percentage of clay present sufficient silica and alumina is provided to use up most of the quick lime in the formation of the simple silicate of lime, or, if the temperature can be raised high enough, the double silicate of lime and alumina, and possibly a separate combination of lime and alumina, called alluminate of lime. Such a lime will not slake and must be ground to a powder, the setting taking place immediately on the addition of water. A compound of lime and iron (if iron is present) may also be formed, but the presence to any great extent of metallic oxides and alkalies prevents the stone being burned at a high temperature on account of their action as fluxes causing fusion of the lime and alumina. In such cases a moderate temperature only can be used, and very probably not enough to cause entry into the combination of the alumina ; and a hydraulic lime composed of quicklime and silicate of lime possessing the power of slaking feebly, and afterwards (when made into a paste) setting, will be the result. From the foregoing it will be evident that a limestone containing sufficient clay, and free from harmful amounts of alkalies or metallic oxides, will have the necessary silica and alumina, and will dmit of being burnt at a sufficiently high temperature to form the double silicate and the aluminate, and will consequently produce a good, strong hydraulic lime. It is, however very rare that the proportion of clay to the carbonate of lime is so well balanced in a limestone, and, moreover, an excess of metallic oxides and alkalies is very probable, consequently the Hydraulic lime produced, as a rule, is the result of burning at a low temperature, and consists of the silicate of lime and a goodly proportion of quicklime, together with impurities.

PORTLAND CEMENT.

95. Portland Cement.—This very valuable cement is an artificially compounded and much improved form of the natural Hydraulic lime. In the foregoing articles, on lime, it has been pointed out that it is a matter of great difficulty to obtain limestone of such a character as to have its constituents properly proportioned in quantity, to render the production of good Hydraulic lime a matter of possibility. With the production of Portland Cement this difficulty is overcome, for the proportion of each constituent is entirely under the control of the maker. The proper quantity of clay is added to the rich limestone to provide the alumina and silica for the necessary chemical action on the lime, and in the selection of the clay and limestone it is possible to avoid the presence of injurious amounts of the metallic oxides and alkalies so that burning may be carried out at a sufficiently high temperature.

96. Process of Manufacture.—There are two methods of making Portland Cement, which are known respectively as the :—

(1) Wet process.
(2) Dry process.

The wet method consists of mixing chalk and clay thoroughly together in water until the consistency of a thickish liquid called "slurry" is reached. The "slurry" is then allowed to settle in tanks for the purpose, and the particles of clay and lime are deposited. After the complete deposition of the particles the water is run off, and the deposited mass is divided and made up into lumps, which are dried, placed in the kiln, and burnt at a great temperature to a condition of hardness. The lumps, which after being burnt hard are called "clinkers," are then ground to a very fine powder, and it is in this state that it is received for use by the Engineer or Builder.

97. The dry process is so named on account of the lime and clay being mixed together while in a dry state. When hard limestone is used, instead of the ready soluble chalk, mixing together by means of water is not possible. The clay is therefore in the dry process first roughly burnt in lumps to a condition of hardness, then added in the proper proportion to the limestone, and the whole ground to powder. By mixing the powder with water a paste-like mass is prepared, which in its turn is made up into lumps. The lumps are dried and calcined, producing the "clinkers" ready for the final grinding.

98. Chemical Composition of Portland Cement.—The analysis of the chemical composition though useful to some extent, cannot be taken as indicative in a complete sense of the quality of the Portland Cement. The use of an

analysis is that it serves to show the presence of a sufficiency or otherwise of the important constituents, and as to whether those having a tendency to be harmful are in excess of the limit; but beyond that it is not of much practical value. The analysis given below is that of a good Portland cement which successfully stood all the usual physical tests.

*ANALYSIS OF A GOOD PORTLAND CEMENT.

Lime.	Silica.	Silica Insoluble.	Alumina.	Ox Iron.	Magnesia.	Potash.	Soda.	Sulphur.	Sulphur Trioxide.	Carbonic Acid.	Carbon.	Water.		
CAO	SiO_2	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	NaO_2	S	SO_3	CO_2	C	OH_2	Chlorides.	Total.
62.70	21·75	0·25	7·61	2·41	0·43	1·00		0·12	1·44	1·25	·10	·94	Traces.	100·00

*Tran's. Royal Soc., N.S.W., 1894, p. 268.

The various constituents as shown by the analysis may be divided into two classes as follows :—

(1) Essentials.

(2) Non-essentials.

THE ESSENTIALS are the lime, silica, alumina, and iron.

The lime enters into combination with silica, and forms silicate of lime, and double silicate of lime, and alumina.

With Alumina	...	Aluminate of lime.
,, Iron	...	Ferrite of lime.
,, Water	...	Hydrate of lime.

THE NON-ESSENTIALS.—The other remaining constituents are of little or no value and practically do not increase the indurative power of the cement. The non-essentials should not exceed 10 per cent.

The constituents are shown by the analysis, given above, to be in proportion, that is to say there is shown to be enough silica and alumina and not much more than enough of lime, whilst those likely to have injurious action are not in excess ; but here the usefulness of the analysis ends, for it is not possible to decide with certainty that the combinations will be perfect. An estimate may be made from the chemists point of view as to the probability of perfect combination, by calculating the theoretical quantity of lime which each acid forming constituent will require, and the following allotment of the lime shown by the analysis in question will be illustrative of this principle.

For the Silica ...	40·41
,, Alumina ...	12·51
,, Oxide of Iron ...	·84
,, Carbonic Acid...	1·62
,, Sulphur trioxide	1·01
,, Sulphide ...	·21
	56·60

which taken from 62·70 leaves 6.10 per cent. of free lime. This it may be

calculated will combine with water to form hydrate of lime. But the hydration of the excess of free lime not taking place, and such is not impossib'e but probable, there is the defect due to the presence of free and uncombined lime. Again, during the setting of the cement decomposition of the more feeble compounds such as those of lime with alumina, and with sulphur, occurs, and more lime is freed. The chemical analysis does not afford information as to the extent of these actions, and hence leaves much to be otherwise determined. It will, therefore, be evident that while serious discrepancies in proportion of constituents, as well as of the occurrence of injurious bodies, will be easily detected by aid of the chemical analysis, it does not in a complete and accurate manner indicate combinations which have taken place during the calcination, and what decomposition *may afterwards* take place when in use.

99. Deval's Hot Bath Test.—The injurious effects, such as "blows," cracks, and disintegration due to the slaking or hydration and consequent increase in bulk of the quick or free lime and to decomposition of the feeble compounds, occur during the setting, but in some cases where the lime is of a slow slaking nature these defects are not developed until after some considerable time has elapsed, so that the time usually allowed for the tests in cold water for soundness is not sufficiently long to allow of the development of the bad points, and a cement might pass for sound and afterwards turn out to be very poor. It has been discovered that cement sets much quicker in hot than in cold water—indeed, so much quicker that a cement kept in hot water for 7 days will be as strong as if kept in cold water for 28 days. This knowledge is taken advantage of to accelerate the setting and so develop evidence of any bad qualities. Pats of neat cement and of cement and sand in proportion of 1 to 3 are prepared, exposed in air for 24 hours, and then placed in hot water of uniform temperature of 180° to 200° Fahrenheit and kept there for 7 days. If at the end of that time there are no cracks or other indications of disintegration the cement may be taken as sound. The pats should be about $\frac{5}{8}''$ thick at centre, and tapering to a thin edge. They should be made on a non-porous surface, such as glass, and kept thereon until set.

100. Texture.—The proper degree of finess of the powder is not less important than the correct proportion of the various constituents and their successful calcination. When used with sand, as it almost always is, the finer the particles the better for it is to be remembered that it is to act as the cementing agent to hold the grains of sand together, and consequently to enable the particles of cement to get round and in between the sand grains they must be as small as possible.

To illustrate the importance of fineness of texture, Mr. Reid, in his valuable "Treatise on Natural and Artificial Concrete," cites a case where a cement of a certain degree of coarseness failed to stand the usual tests, but on being sieved and the coarse particles thereby removed it was found that it successfully survived the same tests. It is generally agreed that the powder should be fine enough to allow of not less than 90 per cent. passing through a sieve having 14400 perforations to the square inch. An average of at least two tests is necessary to form an estimate. The German brands are up to this standard of fineness, and the locally made cement is even of finer texture, but the English brands are, as a rule, a little coarser, only about 75 per cent passing through.

101. Colour.—The colour of the cement powder affords no indication as to quality, and any information in this respect can only be obtained after the "gauging" or mixing with water. Surface as well as section colour of the pat or briquette is taken notice of, and the tests are, as usual in other cases, made on cement with sand (in proportion of 1 : 3), as well as with neat cement. The pats are examined as soon as setting has taken place, and a light grey external surface, with steel grey or bluish section, shows a good kind. Dark greenish drabs or brownish colours are not good, and are expressive of inferiority. The pats of cement mixed with sand are not examined for the colour test until some considerable time (about six months) after the gauging, and the indications are fairly reliable. A light colour at the surface denotes sufficient lime, and a dark or brown colour is taken as being evidence of insufficiency of that constituent. Light indigo section indicates in the case of English cement, good quality, whilst a good German make has a grey section. The best colonial cement has a grey section.

102. TENSILE STRENGTH.—The degree of resistance possessed by the cement against tensile stress is an important point, and in all cases tests should be made. The briquette, as the sample to be tested is called, is made up into a form that will allow of its ends being gripped by jaws which are pulled in opposite directions.

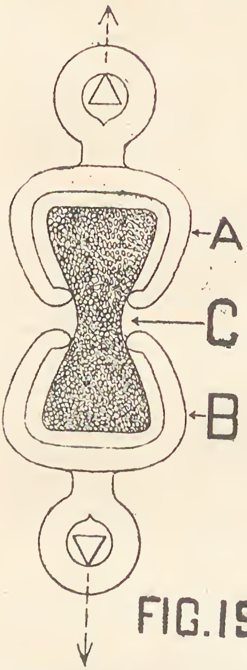


FIG. 19

The most approved form of briquette is shown together with the jaws or shackles by Fig. 19. A, B are the jaws, and C indicates the middle or waist of the briquette at which breaking occurs. This waist is generally one square inch in cross section. Considerable importance attaches to the way in which the briquettes are made, and the particular conditions under which they are kept until put into the testing machine. A portion of the cement to be tested is mixed up neat, and another portion mixed up with sand in the proportion of 1 : 3. The quantity of water used should be not more than enough to enable it to be moulded. A good approximate rule for direction is to take up a handful and squeeze it, when, if the water is not in excess, it will be impossible to squeeze any out of the handful. On no account should too much water be used, for it has been proved that water in excess has a very deleterious effect. An accurate method of determining the amount of water required for any particular class of cement is described by Mr. Roberts (Testing Engineer Department of Public Works, New South Wales) in a paper published in the "Journal of the Royal Society of New South Wales," for 1894, as follows:—"A weighed quantity of cement is placed in a mould into which a piston fits. Pressure* is then applied to the top of the piston by means of a screw, and a spring underneath the mould is depressed to a certain point; water is then poured in around the mould, then the water is first drawn in and afterwards the pressure is released, the cement is then taken out and weighed again, and the difference in weight will give the percentage of water absorbed, which is the percentage that must be used in making the briquettes." The above process is based on the principle that a given quantity of cement of one quality will under a given pressure absorb the same percentage of water. It will be gleaned from the foregoing quotation from Mr. Roberts' paper that the uniformity of the pressure under which the mould, to form the briquette, is filled is also a matter of importance. The pressure is regulated and hence a standard is maintained by having the portions of the mould (the mould is made in two parts to enable the easy removal of the briquette when set) kept together by springs which open out after a certain degree of pressure is exceeded. For testing purposes the sand used should be very clean; and to afford a basis of comparison it is necessary that a standard of fineness should be maintained. The usual method is to pass through a sieve of four hundred holes to the square inch and then through a second sieve of nine hundred holes to the square inch; and that which will not pass through the last sieve is used. As soon as sufficient set has taken place to allow of removal from the moulds, and this should occur before the expiration of the first 24 hours the briquettes are placed some in hot and some in cold water. Great care must be taken that the briquettes do not become dry before being placed in the water Those in cold water are tested at 3, 7, and 28 day periods while those in hot water are tested only at the 7 day period. It may be mentioned here that the cold water periods of immersion include the primal time in air; but the hot watar 7 days is exclusive of the time given for air exposure. The average between 10 tests should be found at each date. The machines for producing the tensional stress are many in kind and varied in detail, but all aim at the exertion gradually

*1400 lbs. per sq. inch. (J.N.)

and without shock of the force, and most of them are on the principle of the lever. One of the best in use is of German design, with a system of two levers, the power being applied in the form of small shot which fall at a uniform rate into a bucket supported at the end of the long arm of the primary lever. The short arm of the first lever is connected to the long arm of the second lever, and so the weight of the shot is multiplied in effect, and acts by way of connection between end of short arm of second lever and the jaws, on to the briquette to be tested. The value of the breaking force is found by weighing the shot (which it must be mentioned ceases automatically to run at the instant of fracture) and calculating the leverage.

A table is given with a view of affording some idea of what a good Portland cement should stand when subjected to tensional stress.

TABLE II.

Minimum Tensile strength of Good Cement.

In Cold Water.	In Hot Water.	Strength in lbs. per square inch.		
		3 days.	7 days.	28 days.
Neat Cement.		300	450	550
One of Cement to three of Sand.			130	200
	Neat Cement.		550	
	One of Cement to three of Sand.		200	

103. Compressive Strength.—The resistance against compressive stress of a good Portland cement should be from 7 to 10 times its resistance to tensional stress. The tests for crushing or compressive strength are made on cubes of varying sizes from 1″ to 9″ sides.

104. Weight.—Heavy cements are considered to be the best, but, as an isolated test, the weight is not conclusive as to quality, for a good cement which has been ground very fine may be light in weight. Viewed, however, in conjunction with other qualifying tests, a cement should not be less than 100 lbs. per Imperial striked bushel. The manner in which the measure is filled will have an influence on the result when weighed, for, when poured in from a height the cement powder will be more dense, or compact, and consequently will be heavier than if just lightly filled in. The proper method is to let the cement fall from a hopper which is held 2 feet above the top of the bushel measure.

105. Time of Setting.—Portland Cements are either quick or slow setting. Those which take two hours or more to set are considered as slow setting. It is most necessary to have an accurate knowledge of the time which any particular cement that is being used will take to set, for, a cement should on no account be worked after the setting has commenced. The most accurate method for arriving at the time at which the setting commences is to fill a metallic cylinder, $1\frac{1}{2}''$ high, and 3″ diameter, with the cement gauged with sufficient water to make a stiff paste. A needle, having a point $\frac{1}{16}''$ square, and $10\frac{1}{2}$ ounces in weight, is then at intervals, allowed to rest, point downwards, and length vertically, on the sample; and the moment at which the needle will fail to pass by its own weight through it, will mark the time of initial set. The cement is considered to be set hard when the needle fails to make any impression on the surface.

106. The following table will afford a very good summary of the foregoing particulars relating to Portland Cement. It is taken from the Portland Cement

test sheet used in the Sewerage Branch of the Department of Public Works, New South Wales, and shows the kinds of tests, and the standard required.

TABLE III.

Showing tests of Portland Cement and standard required by the Sewerage Branch, Department of Public Works, New South Wales.

No.	Description of Tests.	Standard Required.
	Neat Cement set in............	Min. 1¼ hrs., Max, 6½ hrs.
1	Specific gravity.	,, 3·000
†2	Carbon Dioxide absorbed by 3 grammes of Cement.	Max. 2·0 milligrammes.
3	Weight as received, unsifted, per imperial striked bushel.	Min. 100 lbs.
4	Residue on seive of 6400 meshes per sq. in.	,, 20 per cent.
5	Residue on seive of 14,400 meshes per sq. in.	,, 30 per cent.
	Neat Cement with....* per cent. of water	
6	Tensile Strength after 3 days in cold water.	Min. 300 lbs. per sq. in.
7	Tensile Strength after 7 days in cold water.	,, 450 ,, ,,
8	Tensile Strength after 7 days in Deval's hot bath.	,, 550 ,, ,,
9	Tensile Strength after 28 days in cold water.	,, 550 ,, ,,
	1 of Cement with 3 of Sand with....* per cent. of Water.	
10	Tensile Strength after 7 days in cold water.	Min. 100 lbs. per sq. in.
11	Tensile Strength after 7 days in Deval's hot bath.	,, 200 ,, ,,
12	Tensile Strength after 28 days in cold water.	,, 200 ,, ,,
13	Tensile Strength after 3 months in cold water.	.. ..
14	Tensile Strength after 6 months in cold water.	.. ..
15	Tensile Strength after 12 months in cold water.	.. ..
16	Pats of neat cement immersed in water after setting, and similar pats placed in Deval's hot bath and examined day to day for constancy or variation of volume.	
17	Pats of neat cement kept in air to observe for colour.	

*This Quantity is variable, see Art. 102.

†Test for presence of slacked lime.

107. Most of the Cement used at the present is imported, but this material is now being successfully made in New South Wales, Victoria, and Tasmania, and there is every reason to believe that this industry will have a great future, for there are in the colonies, abundant supplies of the raw materials for the production of Portland Cement. Portland Cement is generally supplied in casks, each containing 3½ bushels. Some of the local manufacturers put it up in bags which contain 125lb. net.

108. Plaster of Paris.—The qualities of lime and Portland Cement have been described at some length, for they are almost the only cementing agents used for holding stones and bricks together, and for concrete, in building construction, and consequently they become of great importance from the builder's point of view. There are, however, several other cements in use which, though not so generally useful as lime and Portland Cement, are yet at the same time of value for use in connection with plastering and modelling work, and, therefore, deserve a little attention. The best known of these cements is *Plaster of Paris.* It is prepared from *Gypsum*, an hydrated sulphate of calcium ($Ca.\ SO_4 + 2H_2O$), which is found in a state somewhat resembling rock salt, and from nearly transparent to white, and in colors of greys, yellows, and browns. When pure white it is called *Alabaster;* when crystallised in flattened prisms it is known as *Selenite.* Plaster of Paris is prepared by calcining or exposing the Gypsum in ovens heated to a temperature of about 200° centigrade by which the water of crystallisation is nearly quite expelled, and it is afterwards reduced by grinding to a powder, after which it is ready for use. When mixed with water it hardens very quickly by the reformation of the original hydrate. The Gypsum is often found mixed with a percentage of carbonate of calcium but this addition by no means impairs the value of the plaster, for in such cases the acid of the carbonate is expelled (at the same time as the crystallising water of the sulphate), and quick-lime in addition to sulphate without water results. If

the heating is carried on at a higher temperature than that mentioned above, the re-hydration takes place very slowly, and the setting quality is interfered with; it is therefore necessary to avoid that which is over burnt. During the setting of Plaster of Paris an expansion of about 1 per cent occurs; this may be demonstrated by filling a small glass bottle of the freshly gauged plaster, tightly corking same, and putting on one side until setting has taken place, when it will be found that the bottle will be cracked and burst from the increase in volume of the plaster. Plaster of Paris is useless for work in damp positions, for it is soluble at ordinary temperature in water. It may, however, be remarked that as the temperature is increased the plaster becomes less soluble—at 150° centigrade it is nearly insoluble in water. Plaster of Paris is made in three qualities—superfine, medium, and coarse. It is supplied in casks of 3½ bushels each. The Plaster of Paris used in Australia is imported, but there is a good supply of Gypsum to be obtained in New South Wales, and South Australia, and there is no reason why it should not be prepared for use,

109. KEEN'S CEMENT.—This Cement may be said to be a very much improved kind of plaster of Paris. It was discovered by replacing the residual water of Gypsum by certain saline bodies, such for example, as alum (which is a double sulphate of alumina and potash), that the hardening properties would be much increased. Keen's Cement is made by mixing up the plaster of Paris with a strong solution of alum, re-exposing in a much higher temperature than in the case of the plaster, and then re-grinding to a fine powder.* Keen's Cement sets very quickly, and becomes hard enough to receive a high polish. Keen's Cement is made in three qualities—superfine, medium, and coarse— and is supplied in casks of 3½ bushels each.

110. PARIAN CEMENT.—This is a cement of much the same character as Keen's, but it is claimed that it works much freer when being used—that is to say, it is not so stiff during the period between being mixed and before hardening. It is made with plaster of Paris in a similar manner to that described in the last article (109), the difference being that a solution of borax (biborate of soda) is used instead of alum. Parian Cement is made in two qualities—superfine and coarse—and is supplied in casks of 3½ bushels each.

111. CEMENTS NOT INCLUDED IN THE FOREGOING ARTICLES.—Under this head may be noticed Cements, which owing to the almost general use of Portland Cement, are not now much used, especially in the colonies, but which are of sufficient importance to deserve a little attention, Materials are obtained which require very little preparation to render them suitable for use as cements. The most notable is found in the form of concretionary nodules of argillaceous limestone known as *Septaria*, which when calcined and reduced to a powder make a cement somewhat like Portland Cement, but, of course, not nearly so good This particular kind of cement is known as *Roman Cement*, and was very extensively used prior to the introduction of Portland Cement. It is not much used in the Australian colonies, but it is interesting to note that the Septaria have been found at Geelong, in Victoria, and that good cement has been produced from them. *Magnesian Limestone*, or Dolomite if calcined (at a temperature which is below a dull redness) and reduced to a powder, makes a good Hydraulic Cement. *Puzzolana* is the term given to a material found in France and Italy. It is really nothing else but earth burnt through volcanic agency, but is of great value when mixed with fat lime for making mortar, giving to it the quality of Hydraulicity. The same result may, however, be obtained by reducing bricks, Terra Cotta, or such other kinds of burnt clay, to a powder and mixing with fat lime.

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*See page 515, vol. 34, *Building News*.

CHAPTER VI.

MORTARS AND CONCRETES.

112. SAND.—As sand, or some substitute for it, is used in the preparation of the various mortars and concretes it will be best to deal with it and its various permissible substitutes first. Sand is comminuted stone in loose grains not sufficiently fine to be dust, and occurs in three kinds, which may be classified as follows :—

(a) *Siliceous*, the detritus of silicious or quartz stone.
(b) *Argillaceous*, the detritus of clayey stone.
(c) *Calcareous*, the detritus of lime stone.

That which is generally found and usually used is Siliceous—and, indeed, this is the only one of the three kinds which has the qualifications to fit it for use in constructive work. The others are very fine—almost dust—and are not sharply crystallised. The grains of sand should have sharp edges and rough surfaces, and be thoroughly clean, for, foreign materials, such as clay and organic matter, clinging to them prevents the adhesion of the lime or cement. The grains should also be fairly coarse, the degree of which may be taken to be about that of the standard sand for cement and sand briquette tests (see Article 102 *ante)*.

113. SAND IS OBTAINED for building purposes from sand hills, or banks, pits, river beds, and by crushing sandstone. Sea sand is objectionable on account of the presence in it of salt, which causes it to be continually damp.

Hill, bank, and pit sand is sharp and gritty, but is liable to be associated with clay and other such impurities necessitating careful washing before using it.

River bed sand is clean but is not sharp, the grains being rounded by the action of the water.

Hard white sandstone, crushed, makes an excellent sand, for it is—unless in exceptional cases—clean, and at the same time coarse, rough, and sharp-edged in its granulation. The question of the efficiency of crushed sandstone for sand was exhaustively entered into during the proceedings of the Public Works Inquiry Commission, New South Wales, 1896,* and it was clearly shown that it answered well when made into mortar with cement.

114. TESTS FOR QUALITY.—In ordinary circumstances it is considered sufficient to depend as to its gritty or sharp character on the sense of touch by feeling it with the fingers. The use of a microscope will, however, be more satisfactory in the case of important tests, as the condition of the grains can thereby be accurately ascertained.

The cleanliness or otherwise of sand can be determined by taking about an ounce of it and rubbing it over a clean white sheet of paper, and if clean it should not stain or soil the paper. As to whether salt is associated with the sand is easily discovered by washing the sand in some pure water, after which the water is poured into a test tube and some nitrate of silver added. The presence of salt will be shown by the clouding white of the water.

115. CLEANING SAND.—Coarse impurities, such as twigs, grass, etc., are removed by sifting. Washing is necessary where the impurities adhere to the grains of the sand, and is accomplished by violently agitating the sand in a tank or large cask, at the same time passing plenty of water through it. The water is allowed to run into the tank or cask so that there is a continuous out-flow, by which means the foreign matter is removed in solution or in very fine particles.

116. MATERIALS USED INSTEAD OF SAND.—It is not always possible to obtain sand for use in making mortar, and it becomes necessary to provide something to take its place. The materials which are used instead of sand are :—

(a) *Coal ashes* from furnaces and forges.
(b) *Breeze or Coke* crushed to a coarse powder.
(c) *Burnt clay* crushed to a coarse powder.

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*See pages 268 and 283.

(d) *Scoriæ* } from ironworks, crushed to a coarse powder.
(e) *Slag* }
(f) *Road grit.*

Coal Ashes provided that wood ashes (which are bad on account of the presence of alkalies) are not mixed with them, are good for using with lime to make mortar. Ashes should be well sifted, for there is great liability of impure matter being present. Ashes are also used to darken the mortar for pointing where according to taste a black joint is needed.

Breeze, though not often used, makes a good substitute for sand, especially where crushing strength is not of importance.

Burnt Clay, which, after all, is only brick, is much used where a dearth of sand occurs. It should be thoroughly burned and crushed to be something like a coarse sand in particular size.

Scoriæ and Slag if properly crushed up make good hard mortar.

Road Grit is generally the detritus of hard paving stone (often the very hardest, such as quartz) and makes excellent mortar, the only condition being that it is most necessary to guard against impure materials, such as organic matter of street refuse, manure, etc. It should be well sifted and washed.

117. Casters Sand from iron founderies makes an excellent mortar for use in localities liable to frosts. It is well known that the mortar made from lime and ordinary sand is disintegrated by the action of the frost, and consequently much trouble is caused to the builder. It has been found that the sand which has been used for casting will make a mortar that is not affected by the frost, so that it will thus be possible to overcome the difficulties which have in this particular matter been met with in such districts as for instance the mountainous and southern parts of New South Wales.

MORTAR.

118. Constituents.—Mortar is made up with sand (or its substitute) and either lime or Portland Cement. *Lime Mortar* is generally composed of two parts of lime and one part of sand. The lime should be slacked in a box or tank, passed through a fine sieve while in a liquid form, and then mixed with the sand. By this means the slaking is conducted in a clean way, and the sifting prevents any unslaked particles of lime from passing into the mortar and subsequently causing damage by expansion. Unfortunately, however, this desirable method is not always adopted, for, it is a common practice to just make a heap of the lime, surround it with sand, slake it, and immediately mix the whole together. The constituents should be thoroughly mixed together. In all large and important works the mortar is mixed in mills, which may be briefly described as large circular revolving pans with large grinding rollers working in them—the motion being by horse or steam power. These mills are very economical and especially when burnt clay, brick, slag, breeze, etc., are to be crushed. It is necessary to allow the mortar to stand for about 6 days before using it. *Cement Mortar* is composed of 1 part of Portland Cement to either 1, 2, or 3 parts of sand as the strength requirements vary. One part of cement to two of sand is the proportion mostly adopted. The sand after being washed (if not naturally quite clean) is measured out, and then the cement in its proper quantity is thrown on top of it. The lot is then turned over and mixed while dry, and afterwards the water, which must be quite clean, is added, turning and mixing going on all the time. Cement Mortar is also mixed in mills, when the circumstances of the work in hand render such a course economical. Unlike that made with lime, cement mortar should be used immediately on being mixed up, and on no account should it be allowed to stand sufficiently long for setting to commence. The use of too much water is to be avoided (see Article 102, *ante*). To prevent the incorporation of unclean and foreign matter, mortar of whatever kind should not be made up on the ground, as it often is, but on a timber platform which should be near to the place where the mortar has to be used.

119. Grout.—With a view of having all the spaces between bricks thoroughly filled up it is the practice to reduce the mortar to a liquid condition with water, and so pour it into the space. The mortar when so liquified is called "grout." It is also used for filling the spaces round dowels and joggles, and for running into the grooves of the joints, in masonry work.

120. Strength of Mortar.—Mortar is an important factor in the strength of masonry and brickwork, holding, as it does, by its adhesive and tensile qualities the stones and bricks together, and compressive resistance by transmitting as the bedding material the compressive stress from top to underneath stones or bricks. The strength of a wall or pier will therefore to a great degree (unless in the case of stones, most accurately wrought, and with thin joints) depend on the strength of the mortar, consequently a standard should be observed in calculations of important works, and frequent tests made to ensure adherence thereto.

121. A table is given herewith which will be illustrative of the strength of cement mortar, made with good cement and sand of the quality usually used in work of a good character :—

TABLE IV.*

Showing Strength of Portland Cement Mortar composed of 3 parts of sand and one part of Cement.

Sand put through sieve of 400 holes to sq. in. and caught on one of 900 holes to sq. in.

Kinds of sand.	Tensile Strength in lbs. per sq. inch.				Compressive Strength. In lbs. per sq. in.				Transverse Strength in lbs. per sq. in.			
	30 dys.	90 dys.	6 mth.	12 ms.	30 dys.	90 dys.	6 mth.	12 ms.	30 dys.	90 dys.	6 mth.	12 ms.
Surry Hills	134·7	172·1	201·54	224·42	1932·0	1617·0	2068·7	2025·9	280·5	373 3	457·5	546·2
Liverpool	143·5	165·8	204·7	238·5	1240·7	1569·4	1887·1	1612·9	277·1	381·75	480·9	440·6
Emu Plains (Nepean Sand)	201·14	234·4	280·3	272·0	1854·1	2242·	2459·9	2674·2	376·9	545·5	510.9	562·5
Crush'd Sandst'r	152·74	216·5	244·3	286·5	1100·6	1671·5	1499·4	1532·3	288.6	441·9	516·7	587·4

Records of tests (if such have been made) of lime mortar made with Australian lime are not obtainable, but where strength is of any importance lime mortar is not used, for it is very weak when compared with the splendid Portland Cement now so easily—and indeed cheaply—obtained. It is a matter of difficulty to generalise the adhesive strength of mortar, for the material to which adherence is to take place will have an influence on the result. For instance, a mortar of a certain kind will adhere to a rough, porous stone much better than to a hard, close-grained stone, such as basalt; or to a sandstock, or wire-cut brick, than to a hard glazed facing brick. It will, therefore be clear that the adhesive strength will vary for each different kind of stone, or brick, or other material. As far, however, as the mortar itself is concerned, it will be safe to reckon that its adhesive power will increase directly as the tensile strength increases—that is to say, the more the tensile strength of a mortar the better will be its adhesive power.

122. There can be no doubt that the efficiency of mortar as a binding material is not generally valued to its full extent. A very interesting and valuable series of tests were carried out in India some years ago by Lieut. E. W. Creswell, R.E.,† on beams built of brick in mortar, and the results were surprising. The lime used in the mortar had, when mixed with $1\frac{1}{2}$ parts of sand, a tensile strength of 50lb. per square inch at one month, and 65lb. per square inch at two months. It will thus be seen that when compared with Portland Cement such a lime is very weak. In the experiments in question the mortar was made up with two parts of lime and one part of sand. The beams were 15ft. long, and had a clear space of 10ft., so that the bearing at each end was 2′ 6″. They were 2′ 6″ x 2′ 6″ in cross-section, and the bricks were laid, or arranged, in English Bond.‡ Fifty beams all together were built and tested, and they were classified in five divisions, according to thickness of joint in brick work—That is to say ;—Ten were built with joints $\frac{1}{16}$″ thick ;

*Compiled from valuable evidence given by Professor Warren of the Sydney University before the Public Works Enquiry Commission. See minute of proceedings, page 268.

†For detailed description of these tests see "Roorkee Engineering Papers."

‡See Articles hereinafter for description of bond of brickwork.

ten with $\frac{1}{8}''$ joints ; ten with $\frac{1}{4}''$ joints ; ten with $\frac{1}{2}''$ joints ; and ten with $\frac{3}{4}''$ joints. They were built on solid abutments, and on a centre, as it were, of earth, which was removed just before the imposition of the test load so that they might have a free span. The beams were from nine to eleven months old, and it may be added that the load was applied at the centre of the span. The results are shown by the following table :—

TABLE V.

Showing Strength of Beams of Brick built in Lime Mortar.

Beams 15ft. long, 10ft. clear span, 2′ 6″ x 2′ 6″ cross section, built in English Bond, Load applied at centre of span.

	Thickness of Joints.				
	1/16″	1/8″	1/4″	1/2″	3/4″
Average weight in tons which broke beams.	6·92	7·79	8·12	5·22	4·92

The dead weight of each span of beam was a little over 3 tons.

These tests serve to show that brickwork when carefully built has a very fair amount of strength, and also that joints about $\frac{1}{4}''$ thick make the strongest work.

122a. The following table, showing the adhesive strength of cement mortar has been kindly supplied to the author by Professor Warren, by whom the tests were made at the Engineering Laboratory of the Sydney University :—

TABLE VI.

Summary of tests of Adhesive Strength of Cement Mortars to Bricks.

Description of Materials used in Testing.	Mean of six tests giving the adhesive strength in lbs. per sq. in.			
	Cement.	Sand.	7 days old.	28 days old.
Cement neat	1	-	168	213
,, with crushed sandstone	1	1	117	146
,, ,, ,, ,,	1	2	53	73
,, ,, ,, ,,	1	3	26	48
,, ,, ,, ,,	1	4	16	45
Cement with Bluestone Dust	1	1	79	136
,, ,, ,, ,,	1	2	47	84
,, ,, ,, ,,	1	3	34	45
,, ,, ,, ,,	1	4	23	41
Cement with Nepean Sand	1	1	102	105
,, ,, ,, ,,	1	2	38	45
,, ,, ,, ,,	1	3	20	24
,, ,, ,, ,,	1	4	19	14

The bricks used were made at St. Peters, near Sydney, and gave when immersed in water, an absorption of 7 per cent. "Castle" brand of Portland Cement used. Crushed sandstone put through sieve of 400 holes, and caught in one of 900 holes per sq. inch.

123. Contraction of Materials for Mortar.—The bulk of mortar is less than that of dry materials from which it is made, and for purposes such as estimating cost and for providing for the complete filling up of the interstices between the aggregates in concrete, it is most necessary to be fully aware of the extent of this contraction. The following table affords some useful information :—

*TABLE VII.

Contraction of Cement and Sand when made into mortar.

	One of Cement to One of Sand.	One of Cement to Two of Sand.	One of Cement to Three of Sand
By admixture with water	15·00	16·66	17·50
By admixture with each other	5·00	5·00	5·00
By the Cement setting to hardness from Condition of Mortar	4·00	4·00	4·00
Total Contraction of materials in percentage of their own volume	24·00	25·66	26·50
Total ratio of contraction of materials in percentage of the volume of the mortar when set.	31·58	34·53	36·05

*Portion of a table by Sandeman, p. 256, Vol. liv., Trans. Institute Civil Engineers.

CONCRETE.

124. CONCRETE is the name given to a mass or body composed of gravel, pebbles, broken stone, or some other hard substance, cemented or bound together with mortar. Concrete may therefore be divided into two classes of constituents viz :—

(a) The *aggregate*, or the whole of the pieces of broken stone, gravel, or pebbles.
(b) The *matrix*, or the mortar which binds the aggregate together.

125. *The aggregate* may be composed of any of the folllowing materials :—Broken stone, broken bricks, pebbles, breeze, and, indeed, any hard substance which may be broken up in the same manner as stone ; gravel, and shingle, from river beds are also very suitable. In building-work the kind usually used is either hard stone, brick, or gravel for foundations, piers, and such work where great strength is required ; and breeze where lightness is a consideration, as in ceilings and coved work. The material for the aggregate is reduced or broken by hand with a tool called a "knapping hammer," and also by means of stone-breaking machines driven mostly by steam power. It is a matter of impossibility to evenly break the stone, and necessarily a variety of sizes, and also a quantity of very small pieces, which are reduced almost to sand, are produced. Screening is therefore necessary to obtain pieces within a certain range of size. In the case of machine stone-breakers a screening apparatus is attached, so that the pieces of different sizes are separated. When broken by hand the stone is usually screened also by hand. The aggregate should be well washed, so that any extraneous matter may be removed.

126. SIZE OF THE AGGREGATES.—The gauge to which the stone or other material is broken varies according to circumstances, but mostly it is specified that the aggregate shall not be more than $1\frac{1}{2}''$ or $2''$ in size. The Engineers of the Sewerage Construction Branch of the Department of Public Works, New South Wales, arrange in their specifications for blue stone to be broken so that the largest piece shall pass through a ring $1\frac{1}{2}''$ in diameter, and that it shall be screened on a sieve $\frac{1}{8}''$ mesh. The Engineers of the same Branch Department specify that sandstone shall pass through a ring $2''$ in diameter, and also be screened in the same manner as bluestone. Aggregates are, however, often made much larger in special cases, and for such purposes as pavements they are prepared so small that the largest pass through a $\frac{3}{4}''$ ring.

It is generally admitted by authorities that it is best to leave the "Shivers" or smaller pieces in, than to screen the aggregates so as to have them all of the one size—that is to say, it is better to have the aggregates ranging in size from what will just fail to pass through a $\frac{1}{8}''$ sieve, to $1\frac{1}{2}''$ or $2''$, as the largest are specified to be. The argument in support of this being that the smaller pieces fit in between the larger ones, and so in a substantial manner aid to fill up the voids which would otherwise require to be altogether filled up by the matrix.

It is a very important matter to accurately ascertain the percentage of the spaces or interstices between the aggregates, for it is this percentage of space which determines the ratio of the volume of the matrix to the volume of the aggregate. The table here following gives percentages in several kinds of material, but experiments will have to be resorted to in most cases to find the percentage of void :—

*TABLE VIII.

Table showing ratio of interstices in Aggregate for Concrete.

	RATIO OF INTERSTICES.
Broken limestone the greater part of which would be gauged by a 3'' ring.	50·9
Gravel screened (free from sand), small pebbles, and pieces guaged by a 2½'' ring,	33·6
The above limestone and gravel well mixed in equal proportions.	33·6
Sandstone varying in size between pieces gauged by a 4'' ring and pieces gauged by an 8'' ring.	50·0
Sandstone varying in size between sand and pieces guaged by a 4'' ring.	34·0
The above two sandstones mixed in equal proportions.	36·0

*Portion of table by Sandeman, p. 218, Vol. CXXI, Trans. Inst. C. Engineers.

127. THE PERCENTAGE OF VOID in any kind of aggregate may be determined by filling a vessel of one cubic foot capacity, with the aggregate, and then pouring water in, so that all the interstices may be filled. The quantity of water required to fill the interstices will show the percentage of void per cubic foot.

128. THE MATRIX OR MORTAR.—The materials for and methods of making mortar have already been described, consequently it will at this stage be only necessary to deal with the question of proportion. It may, however, be noted that concrete is made with lime mortar as well as with cement mortar, though, of course, cement is the most used on account of its great superiority in the matter of strength and also hydraulicity. The author is aware of at least one large building just outside of Sydney, the foundations of which are made with lime concrete, and it has answered quite well. There is also a house on the Blue Mountains, New South Wales, which has all the walls built of this lime mortar. These examples are only given to illustrate the fact that it is not only Portland Cement that may be used in making concrete.

129. PROPORTION OF MATRIX TO AGGREGATE.—It is most important that the matrix should thoroughly fill up all the voids or spaces between the aggregates, and not only that, but also be sufficient to get between the pieces of stone and cement them together. About ten per cent is added to the percentage of void to ensure all voids being filled and sufficient mortar being provided to cement the aggregates together. Another thing also which must be remembered is that the mortar when set is less than the bulk of the dry materials (see table article 123 *ante*). This percentage of contraction must be added to the percentage of void.

To illustrate the above :—

Let X = The percentage of void in any particular kind of aggregate.

,, Y = The amount of excess (usually ten per cent.) to ensure presence of sufficient mortar to cement pieces together as well as fill all voids.

,, Z = The percentage of contraction of dry material when set into hard mortar.

,, A = Total percentage of volume of dry materials of matrix to volume of aggregates.

Then A = X + Y + Z.

The proportions for foundations and walls, roughly put, may be taken as follows :—

Aggregates (from $\frac{1}{8}$ in. to 2 in.) 5 parts ; sand, 2 parts ; cement, 1 part.

Aggregates (from $\frac{1}{8}$ in. to $1\frac{1}{2}$ in.) 4 parts ; sand, 2 parts ; cement, 1 part.

130. Mixing of the Materials to make Concrete.—The amount of each kind of material is determined by measuring in gauge boxes which are proportioned in capacity as the specified relative quantities of aggregate and constituents of the matrix. To make this quite clear—let it be supposed that the relative quantities of stone, sand, and cement are represented by the ratio 4 : 2 : 1, and taking the cement box to be 4 cubic feet, then the capacity of the sand and stone boxes would be 8 cubic feet and 16 cubic feet respectively.

Builders generally please themselves as to the shape of theses boxes, since the only important matter is that of correct proportional capacity ; but by way of completing the above illustration it may be as well to set down one arrangement of sizes which would provide for the above-mentioned proportional capacities—

The cement box might be $2' \times 2' \times 1' = 4$ cubic feet.
The sand box might be $4' \times 2' \times 1' = 8$ cubic feet.
The stone box might be $4' \times 4' \times 1' = 16$ cubic feet.

A box for the cement is not, however, usually made, for cement barrels mostly contain 4 cubic feet, and the other boxes are (as in the example above given) made multiples of this capacity.

The process of gauging and mixing is carried out on a sawn timber platform as follows:—The stone box is first filled with stone and then emptied, and the stone spread out so as to be level at the top. The sand box is then placed on top, is filled and emptied, and the sand heap levelled out in the same manner as the stone. The cement box is next placed on the sand, filled and emptied. The whole heap is then completely turned over from its position to another one on the platform and then back again. Water is then gently sprayed on to the heap while it is being twice again turned over on the platform. Care is to be exercised that too much water is not used, for excess washes away the fine and useful cement, and is otherwise injurious as pointed out in article 102 *ante*, and there should not be more water in the concrete than shall just show moisture on the surface when rammed.

The foregoing is descriptive of the process as accomplished by hand power, but (as in the case of mortar making) there are many kinds of concrete mixing machines which are thoroughly effective as mixers, and also are—where there are large quantities of concrete to be mixed—very economical. Concrete should not be made up on a windy day, for the wind removes a great portion of the fine cement.

131. Laying Concrete.—The concrete should be mixed near to where it is to be used, and then put in its place as quickly as possible—at any rate, it should be laid and rammed before setting commences. It is usual to remove it in barrows, or skips, from the mixing platform ; and the "tip" or fall from the barrow or skip should not be more than 18″ or 2ft·—with a greater fall the heavier portion, such as the stone, has a tendency to get to the bottom of the body of the concrete, and thus destroy its uniformity of composition. After tipping from the barrow or skips it should be shovelled out, trodden, and rammed. Concrete is not laid in greater thickness than in layers 9″ or 12″ at a time. These layers should be perfectly horizontal, should be accurately set, and the surface of each should be thoroughly clean and wet before laying the next. Concrete should be protected, until fully set, from the effects of the sun ; and rain should not be allowed to fall on it until after the initial set has taken place.

132. Strength of Concrete.—Table IX, here following, has been compiled from valuable and interesting information, contained in three tables,* showing results of experiments by Mr. John Grant, M.I.C.E., as to the strength of concrete. The quality of Portland Cement has improved since these tests were made, and experiments made with similar aggregates, and under equally skilful supervision, would, it is certain, give much higher results.

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*See Tables IV., V., and VI., page 297, Vol. XXXII., Trans. Inst. Civil Engineers,

TABLE IX.

Showing Strength of Concrete Blocks.

The size of each block was 12// x 12// ; and the concrete composing each was well rammed or compressed.

Cement weighed, when sifted, 110·56 lbs. per imperial striked bushel. After seven days in water neat cement broke at 427 lbs. per square inch.

Materials for Aggregates which it is presumed were so broken †as to contain a percentage of pieces sufficiently small to make enough sand to mix with cement to form matrix.	Weight in tons which crushed the blocks.					
	Proportion 6 to 1		Proportion 8 to 1		Proportion 10 to 1	
	Kept in air.	Kept in water.	Kept in air.	Kept in water.	Kept in air.	Kept in water.
Ballast	80·50	91·00	61·50	76·00	48·50	48·00
Portland Stone	118·00	138·50	110·00	126·50	72·60	78·00
Granite	113·20	96·50	73·80	84·60	49·80	60·50
Pottery	109·20	136·50	97·50	118·00	90·00	100·00
Slag	110·50	111·00	85·20	70·00	60·00	52·00
Flints	116·00	126·00	103·50	117·50	70·00	98·00
Glass	99·00	112·50	65·00	94·00	53·00	75·00

†Whether this was so, or not, was not made clear in the description of the experiment.

CHAPTER VII.

BRICKS.

133. Clay, from which bricks are made, is one of the products of the decomposition of rocks, such as granite, gneiss, mica, slate, and most kinds of basalt and trachyte, which contain aluminous minerals. Rain water, acids in the atmosphere, sea waves, and such other agents of denudation are always causing decomposition of rocks. and the particles thereof so disturbed are carried off in suspension by the water, and finally deposited either on the sea-beds, in the estuaries of rivers, or on the banks of the latter during their over-flow,

The immense beds of clay accessible at the present time have been accumulated by such means, and, owing to geological disturbances and adjustments have been elevated to positions above the level of sea, lake, or river. Generally these beds are of a yellow to reddish colour, and loose formation at top, with a tendency to white and compactness as the depth increases, while at a great depth below the surface they become a bluish grey compact shale. The reddish colour at the surface is due to the iron contained in the clay becoming oxidised through the action of surface water and atmospheric influence. There are, of course, cases where iron is practically absent, and hence a white colour at the surface.

134. Pure Clay, or kaolin as it is called, is a hydrated Silicate of Alumina; and, of the constituents of the rocks particularised above, the one that yields this pure clay is felspar, which is a Silicate of Alumina plus a small quantity of alkalies, which are leached out during weathering or decomposition. Clay is, however, rarely found in a pure state—indeed, only in such cases where the felspar has been decomposed *in situ*, for, during the translation by water the particles become associated with impurities such as lime, magnesia, iron oxide, organic matter, etc. It will, therefore, be apparent that brick clay, generally, is a material composed mainly of silica and alumina, with water for hydration, together with small proportions of metallic oxides, lime, alkalies, etc.

135. Table X., on following page, gives the chemical composition of samples of some Australian clays, and also of pure Kaolin and Stourbridge fire clay.

136. A great deal depends upon the relative proper proportions of the essential constituents, and on the absence of more than a certain maximum amount of those which have an injurious tendency. Hence it will not be going outside the legitimate scope of these articles to enter into some explanation as to the character and functions of each of the various constituents.

137. The essential constituents are, as before noted, Silica and Alumina. Lime, magnesia, iron oxide, and alkalies are, however, generally met with, and are under certain conditions useful, as will be explained later on ; but in excess these bodies are injurious.

138. Iron pyrites, common salt, and organic substances are frequently found in brick clays, and are all injurious in direct proportion to the quantities which may be present.

139. Silica (oxide of silicon) is essentially an acid oxide, infusible unless in the very highest temperature, and occurs in three forms :—Crystalline, or quartz ; amorphous or flint ; and in combination with other bodies. It exists in a state of combination with Alumina as *Silicate of Alumina* in all clays; and in most, also, in a free state, as flinty quartoze grains known as sand.

140. Alumina (oxide of aluminium) is practically infusible. Like Silica, it occurs in great abundance, and forms an essential constituent of brick clay. The paste formed by mixing it with water is very plastic, and shrinks very much if dried and heated.

141. The combination of Silica and Alumina forms the Silicate of Alumina, which, when hydrated, is the pure clay or kaolin. This Silicate of Alumina is very refractory, and becomes very hard when subjected to heat ; but it shrinks very much, and consequently bricks made from it are twisted and warped out of shape. An excess of alumina only increases the shrinking and warping

TABLE X.

Chemical Analysis of Brick Clays.

No.	Description of Specimen.	Locality.	Moisture at 1000 C.	Combined Water.	Silica.	Alumina.	Ferric Oxide.	Ferrous Oxide.	Manganous Oxide.	Metallic Copper.	Lime.	Magnesia.	Potash.	Soda.	Phosporic Acid.	Sulphuric Acid.	Titanic Acid.	Organic Matter.	
1	White Clay.	Dubbo, N.S.W.	1·09	13·38	45·27	39·05	1·08	—	—	—	—	·22	·32	—	trace	—	trace	—	100.41
2	White Clay.	Mudgee, N.S.W.	·34	3·71	73·28	18·00	·54	—	—	—	·37	·33	·07	3·73	—	—	—	trace	100.37
3	White Clay.	Milton, N.S.W,	6·85	11·35	45·79	34·54	·90	—	—	—	·31	trace	·65	trace	trace	—	—	trace	100·39
4	Hard Black Clay.	Bourke, N.S.W.	4·01	8·29	52·52	25·79	7.48	—	trace	—	·68	·54	·58	—	trace	—	—	trace	99·89
5	Soapy Clay.	Parkes, N.S.W.	7·65	4·62	50 68	18·71	12.51	—	trace	—	·52	2·28	1·34		trace	1·69	—	—	100·00
6	Dark Grey Clay with plant impressions.	Richmond River, N.S.W.	3·05	4·63	63·02	20·96	2·94	—	—	—	1·32	1·06	2·90	·44	·04	trace	—	—	100·36
7	Shale.	Mount Pleasant Coal Mine, N.S.W.	1·48	4·61	68·28	21·29	·87	—	—	—	·30	·70	1·86	·31	—	—	trace	trace	99·70
8	Dark Green and Purple Grey Clay Shale.	Sydney, N.S.W.	3·38	5·32	56·28	24·21	7·34	—	—	·08	1.10	2·36	—	—	—	—	—	—	100·07
9	Clay.	Lillydale, Victoria.	Water 4·81		67·92	21·72	3·72	—	—	—	·62	·66	—	—	—	—	unestimated .55		100·00
10	Black Clay found under coal measures.	Stourbridge, England.	Water and Organic Matter. 10·30		63·30	23·30	—	1·80	—	—	·73	—	—	—	—	—	—	—	99·43
11	Pure Kaolin.	England.	Water 13·90		46·30	39.8	—	—	—	—	—	—	—	—	—	—	—	—	100.00

Nos. 1, 2, 3, 4, 5, 6, 7 and 8 from Reports Department Mines, N.S.W. No. 9 from Report Department Mines, Victoria. No. 10 from p. 122 "Notes on Building Construction" (Rivington). No. 11 from p. 110, Vol. 68 "Builder."

tendencies. On the other hand, as the quantity of silica is increased so is the liability to shrink reduced, while the refractory properties are in no way interfered with. Whatever quantity there may be, free, and in excess, will be in the form of quartoze or flinty sand, and the more there is the more brittle will be the substance of the brick. It follows, then, that silicious sand may be added to "strong" or pure clay to prevent the warping and twisting due to shrinkage, so that a shapely brick may be produced ; but at the same time it must be remembered that the brick will be of a crumbling and unstable nature, for, the heat has no power to even partially melt the grains of sand and so produce adhesion throughout the mass. A brick should have the constituent bodies consolidated into a partially vitrified mass, so that, while being shapely, it shall be, throughout, thoroughly hard and compact.

142. THE MOST POWERFUL BASIC BODIES, such as alkalies and oxides of iron, combine readily with Silica, and the silicates so formed when exposed to high temperatures become vitreous. Silica also combines with lime, and under the action of great heat vitrification takes place ; but not to such a great extent as in the case of the bases before mentioned. Alkalies, oxides of iron, and lime are therefore useful as fluxes to produce the vitrification necessary for a hard brick, and when not present naturally, one or the other may be added. There is, of course, a limit to the quantity, for too much of these fluxes produce the very worst results, because instead of bringing about a partial vitrification, an excess causes the whole mass to melt, run, and become shapeless.

143. Owing to the number and varying proportions of the constituents of ordinary brick Clays, many extremely complex compounds are formed. In the articles immediately preceding this a pure or "strong" Clay was dealt with, and the author pointed out that though very refractory, it was liable to warp and twist, and that this troublesome tendency could be overcome by providing an excess of silica in the form of sand—an improvement which, however, was in a great measure counterbalanced by the disadvantages attending the friable and crumbling brick which would result. But this defect could, it was stated, be avoided by providing also for the presence of some materials which would render the silica and alumina more fusible, and so partially melt and form into a semi-vitreous mass. So far so good ; but it is by the presence of these necessary additional bodies, together with impurities which practically are impossible of avoidance, that serious complexity occurs.

144. As before noted, the Silica is ready to combine with the basic bodies such as potash, soda, the oxides of iron, lime, magnesia and alumina. Moreover, some of the oxides of the earthy metals are among themselves likely to combine. Compounds are consequently formed, the exact behaviour of which, under the influence of heat, it is not an easy matter to determine, and cannot very well be entered into here. A general notice of some of the main points connected with these compounds is, however, unavoidable.

145. A compound of silica with one base is much more difficult to fuse than a compound of silica and two or more bases. That is to say, a double silicate of lime and alumina is more easily fused than a silicate of alumina ; and so on. Again, the bases differ as to their power of causing fusion, as follows :—

Commencing with the most powerful, and proceeding in order— Alkalies, oxides of iron, lime, magnesia and alumina. Moreover, the power to cause fusion of the fluxing bases, such as alkalies, oxides of iron, and lime varies as the proportions of the other earth oxides differ. For instance, oxide of iron causes fusion at a comparatively low temperature if the silica and alumina be in equal proportions.

146. The impurities of useless, and more or less dangerous character, which are commonly found in brick Clays are iron pyrites, pebbles of carbonate of lime, organic matter, and common salt.

147. Iron Pyrites (*bisulphide of iron*) is often found in clay—mostly in shale. This substance is very hard, and has a brassy-yellow color. It should be removed from the clay, for if left it is very likely that only partial decomposition will take place during the burning process, and oxide of iron and basic sulphides of iron remain, so that afterwards, when exposed to air and moisture, an extension of oxidation takes place, sulphides of iron are formed, and possibly also the sulphur will attack the lime, forming sulphate of lime. Oxidation causes an increase of bulk, the

sulphates in forming crystallise, and these actions split the brick and disintegrate it.

148. LIMESTONE PEBBLES are a fruitful cause of trouble if allowed to remain in the Clay, for during burning the CO_2 is expelled, and the pebble is turned into a lump of *quick-lime*, which will slake directly the brick is subjected to the action of moisture, and splitting will result.

149. ORGANIC MATTER, if not completely destroyed by the heat, causes, in many cases, the exudation of compounds of a soluble nature which discolour and disfigure the surface of the bricks. The presence of organic matter is generally objectionable and should be avoided.

150. COMMON SALT is generally found in more or less quantity in Clays of marine deposition. It is a very objectionable impurity, possessing, as it does, the power of fluxing in the highest degree, and it is on that account impossible to burn clay containing it into hard bricks

151 The proportions of the various Constituents in any kind of Clay are, of course, shown by chemical analysis, but the information thus obtained is not alone sufficient for all practical purposes, for the analysis does not clearly show the kind and extent of the combinations formed by the different bodies. As an illustration of this, take the case of silica A chemical analysis will show the exact quantity present, but it does not show how much is in the state of sand, and what quantity is in combination with other constituents As explained in connection with cement analysis, an experienced chemist may be able to make a fairly reliable calculation as to the kind and extent of the combinations by an inspection of the analysis; but in the case of Clays, at any rate it has been so far the rule, that in addition to the chemical analysis, a careful microscopic examination and trials of the Clay have been necessary to arrive at a just estimate of the value of a Clay for making and burning into a shapely and hard brick.

152. Concerning the analysis, it may, in a general way, be taken that for good ordinary bricks the silica may range from 60 per cent. to 70 per cent., and the alumina from 18 per cent. to 24 per cent.; the balance percentage of the other constituents in no case being over 16 per cent. The silicates should, however, not be over 4 per cent. of the whole clay. In the Table X., Art. 135, examples of English fire Clay and kaolin (Nos. 10 and 11) have been inserted to form a basis of comparison to estimate some of the Colonial Clays. The representative range of the Australian Clays is not as satisfactory as it might be owing to the difficulty to get records of tests; but those available, and inserted in the table, have been made by experienced and able analysts in the official service of the Provinces indicated, and, so far as they go, may be taken as reliable. Nos. 1 and 3 are very "strong" Clays, and would be liable to shrink; obviously sand would be needed in making bricks from these Clays. No. 2 was experimented with, and stood a very high temperature successfully, as would be expected from the large amount of silica and the small quantity of fusion-causing materials. Examples 4, 5, and 8, contain too much iron oxide to allow of being burnt into good bricks. No. 5, is especially poor, and is inserted to illustrate a really bad Clay. A trial was made with No. 6, with the result that a fairly hard, reddish colored brick was obtained; it, however, contains about the limit of the constituents other than silica and alumina.

153. COLOR OF BRICKS.—The impurities contained in the brick-clay have an important influence on the color when burnt, but the conditions surrounding the burning also have much to do with the appearance of the finished brick, and to produce any particular color, the method of burning as well as the constitution of the clay must be taken into consideration. It is, unfortunately, not the general rule with Colonial brick-makers to scientifically deal with the question of color, for, most of them are content to proceed by rule of thumb methods, which are the results of their local experience; and anybody who has had to do with obtaining supplies of bricks of any particular tint knows how uncertain and unsatisfactory these methods are. There can be no doubt that this difficulty to get uniformity of color has a very bad effect, for it prevents the legitimate use of bricks in Architectural ornamental work, and has a great deal to do with the abominable practice which has become so general during late years of plastering the brickwork over with Cement Stucco finished in imitation of stone. The beautiful brick architecture of Southern Europe is particularly suitable for the Australian climate, and its adoption should be encouraged by the brick manufacturers directing their efforts towards

the production of bricks of presentable appearance, and uniformity in each kind of color.

154. BRICKS may be produced ranging from white to black, and from cream, buff, brown. all kinds of red, to dark blue and purple ; and it should be possible, with the aid of careful examination of the clays at hand, and judicious mixing, to produce any number of bricks of any particular tint of these colors.

155. IRON OXIDE has a great deal to do with the color, for it is very seldom altogether absent from brick clays, and by its influence, principally, cream, yellow, orange, light red to dark red, dark blue and even black are produced. Lime in conjunction with iron has also an important part to fulfil, and where naturally not present is often added ; but care is always taken that it is supplied in a very fine state to prevent trouble as explained in Article 148 *ante.*

156. DESCRIPTION OF COLORING CONSTITUENTS.—A necessarily brief description of the constitution of the clays to produce white and the various colored bricks is given below :—

- (*a*) WHITE.—Clay containing iron and small quantities of other impurities, with a fair amount of lime added to it, will burn into white bricks if subjected to a high temperature, which causes the formation of a ferri-alumina-calcic silicate, in which combination the red color of the iron oxide disappears. The pure clay or kaolin will burn into a white brick, but, as before pointed out, it is liable to warp and twist in the kiln. The method adopted to overcome the warping is as follows :—A certain large proportion of the clay is mixed up and burnt into ballast, after which it is ground up and added to the raw clay. The whole is then worked up, moulded into bricks, and finally burnt.
- (*b*) CREAM.—Clay containing a fair amount of iron oxide, with lime added, but not burnt at such high temperature as in the case of white bricks.
- (*c*) YELLOW.—Clay with a little lime, and fairly large amount of iron oxide, fired at a moderate temperature.
- (*d*) BROWN.—Clay containing 3 to 4 per cent. of magnesia.
- (*e*) LIGHT RED TO FULL RED AND DARK RED.—Clay containing oxide of iron, with lime altogether, or practically, absent. The degree of red increasing as the temperature is raised.
- (*f*) DARK BLUE AND ALMOST BLACK.—Manganese in presence of iron oxide, or iron oxide present to the extent of more than 10 per cent., gives a dark purple blue when fired at a high temperature.
- (*g*) LIGHT BLUE.—Pure clay with phosphates of lime and alum added.

The fancy colored bricks are burnt in close kilns, and good common qualities of attractive color are got from open kilns ; but the common brick from the now almost generally used patent, continuous kiln on the Hoffman principle, is of a pale and uninviting color, due it may be suggested either to the bleaching action of the aciduous fumes in the close chambers, or to the possibility that the oxygen admitted is sufficient only for the needs of combustion, and oxidation of the iron does not take place, for it may be noted as a significant fact that bricks of the same constitution put in the old kiln burn a strong red color.

157. From the foregoing it will be seen that the impurities, such as lime and the metallic oxides, which are contained in the clay, are the cause of the color of the bricks when burnt, but it may be noted, that, except in some of the cases, they effectually produce the desired color without requiring to be present in sufficiently large quantity to prevent a sound and durable brick being produced. The production of a light cherry red color is a case in point, however, where the colour requirements prevent a very hard brick being made, for the iron has to be present in fairly large quantity, and the temperature of burning cannot be high, consequently a hard brick is impossible.

158. ENAMELLED BRICKS.—It is now the custom to largely use white enamelled brick for such purposes as the facing of walls of ill-lighted rooms, like cellars, and for walls of light areas to increase their effectiveness, as well as for lavatories and such other places, where cleanliness in reality as well as in appearance is amatter of importance. White enamelled bricks are not, however, the only kind used,

for, in external brickwork of an ornamental character, enamelled bricks of various colors are in many instances used. The glazing, or enamelling, on the bricks is produced in much the same manner as that on pottery—by immersing the faces to be glazed in a glazing composition, which is in a liquid form, and then reheating them until the composition fuses and forms a glassy surface. There are many kinds of glaze compositions, but the following, by Mr. W. D. Clark, will be found as good as any, provided that judgment and care is exercised in their use. It may be mentioned, that the bricks, which of course are of first-class quality, are burnt in the ordinary way before applying the glaze.

TABLE XI. *

Showing Composition of Glaze for enamelling Bricks.

In each case the constituents to be taken together in a retort and calcined, then reduced to powde and mixed with water to the consistency of cream. To be applied by immersion therein or with a brush.

CONSTITUENTS AND PARTS BY WEIGHT.

Finished Color of Enamel.	Feldspar.	Flint or Quartz.	Paris White.	Oxide of Zinc.	Boracic Acid.	Kaolin.	Black Oxide of Manganese.	Black Oxide of Cobalt.	Oxide of Uranium.	Brandon Mineral Paint.	Potters Blue	Oxide of Copper.	Lime	Sub Oxide of Copper.
White ...	80	70	65	50	50	12	—	—	—	—	—	—	—	—
Black ...	80	70	65	50	52	12	2	1	—	—	—	—	—	—
Blue ...	80	70	65	50	52	12	—	2	—	—	—	—	—	—
Yellow ...	80	70	65	50	52	12	—	—	2	—	—	—	—	—
Drab ...	80	70	65	50	55	12	—	—	—	6	1	—	—	—
Green ...	80	70	65	50	52½	16	—	—	—	—	—	2½	—	—
Red ...	80	70	65	50	52½	8	—	—	—	—	—	—	4	2½

*Compiled from text, page 78, "Bricks, Tiles and Terra Cotta" (Davis).

159. BRICK-MAKING.—The production of bricks may be carried on with a very small and unpretentious plant—a pick and shovel, rough made moulding table, moulding tools, drying shed, and an old-fashioned open kiln; but in populous districts where a large amount of building work goes on, the plant, consisting of building machinery and patent kilns generally represents a capital outlay of many thousands of pounds, for in the case of brick-making, as in almost everything else, the introduction of machinery, and the results of invention, have made a great change in the methods of production, so that, the old time style of making by hand is gradually disappearing, and in the cities and large towns hardly anything else but machine-made bricks are supplied. Before passing on it may, however, be noted that amongst builders of conservative tendencies there is the constant complaint, that the bricks made by machinery at the present time are not nearly so good as those made in the old days by the hand process; but there is nothing to support this contention, as the evidence afforded by comparative tests shows that the bricks now made by machinery at many of the establishments have for all round qualities never been equalled by hand-made bricks.

160. THE METHODS OF MANUFACTURING BRICKS may be classified under two heads, viz:—

(1) WET CLAY, or plastic process.

(2) DRY CLAY process.

161. WET CLAY is, of course, used when bricks are made by hand power, but, machines for making bricks with wet clay preceeded those on the dry clay system, and are still extensively used, even in brickworks which are conducted on a large scale.

The manufacture of bricks by hand power alone is, as pointed out before, almost entirely a thing of the past; but, it is impossible to pass on to the description of the modern methods of machinery without briefly dealing with the old fashioned way of making bricks, for, under certain circumstances at the present time, as for instance away out in the "back blocks," it is only requisite to make on a very small scale, and machinery is unnecessary.

162. BRICKS MADE BY HAND.—The clay after being excavated is spread out and allowed to remain exposed to the disintegrating effects of the weather. By such means pebbles of limestone, and iron pyrites are decomposed. It is next "tempered," that is, turned over and over, and well worked until it is in the condition of a plastic mass. The sand, which is largely used when making bricks by hand, is added during the tempering process. When properly tempered and ready for being made into bricks it is conveyed in lumps to the moulder's table, where it is received by the assistant, generally a youth, who cuts off a portion, about sufficient to make a brick, which portion he rolls and works up, and passes to the moulder. The mould is a wooden box or frame without top or bottom, 10″ long, 5″ wide, and 3⅜″ deep. A piece of wood about one inch thick, and of a size to form a bottom for the mould, is nailed to the table. On this piece of wood or "Stock" as it is called, is fixed another but much smaller piece, and which is pyramidical in form. This projection forms the indent known as the "frog" on the bottom face of the brick. To make a brick, the mould is dusted with sand, and placed on the stock, and the portion of clay received from the assistant, is pressed by the Moulder into it, so that the clay fills every part. The superfluous clay is then struck off with a wooden lath, and the mould is lifted up, and the brick deposited from it on to a thin piece of wood called a "pallet board," on which the brick is conveyed to the "off bearing" barrow. The barrow, when full, is wheeled to the drying sheds, where the bricks are stacked until dry enough to put in the kiln and burned. The drying of the bricks lasts from two days to a week, according to the condition of the weather.

Tempering by hand is a very primitive method and a pugmill is almost always used for grinding and mixing clay. A pugmill is a machine consisting mainly of an upright shaft, armed with knives, which revolves in a hollow cylinder containing the clay; the revolution of the shaft being caused by horse power.

163. PLASTIC PROCESS BY MACHINERY.—The clay is first put through a grinding machine, the rollers of which reduce all lumps and pebbles. From the grinding machine it is run into a pugmill, wherein it is mixed and kneaded. The shaft of the pugmill is fitted with a screw-like arrangement which forces the kneaded clay out through an opening at the end opposite to that where it entered. This opening is rectangular in shape—the size of the rectangle being about 10″ x 5″. The clay therefore emerges in a continuous band 10″ x 5″ in cross section, and is directed on to a metal table. When about sufficient to make 12 bricks has passed on to the table, a cut is made across it to sever it from the other part of the band. The section on the table is then made to pass through a frame containing 13 vertical wires, 3⅜″ apart, which cut the band into bricks. The bricks are then removed in barrows, and stacked to dry in the same manner as if they were hand-made. The whole of the machinery is driven by steam power, which is so contrived as to cause all the movements of the wire cutting of the clay band into bricks, as described. The bricks so made are rough on the surface formed by the cutting of the wires, but they are really good bricks when well burnt. For important work, where appearance is of consequence, the bricks are afterwards pressed in a pressing machine, generally worked by hand, which forms good faces and sharp edges.

164. THE DRY CLAY PROCESS is the method mostly adopted where machinery is used, on account of the advantages offered in the way of speedy production, and it is also said to be less costly; but it is questionable whether the bricks are as good as those made by machinery with wet clay.

The following is a description in a general way of the process of making bricks with dry clay:—

The clay, after being excavated, is roughly mixed and put into trollies, which are hauled up an inclined railway, by means of a cable gear, to the building containing the grinding and moulding machinery. Each trolly is fitted with a collapsible bottom which is released when above the grinding machine, and the clay is deposited into a shoot that conveys it to the pan in which it is ground. This pan, which is continually, and horizontally revolving, is circular in plan, and of considerable diameter, but not very deep. A couple of large rollers, somewhat like grindstones in form, but composed of cast-iron, revolve with a vertical circular motion in the pan, and by their weight crush and reduce the clay to powder. When so reduced the clay passes out through small holes, of which there are a great number in the

bottom of the pan, and into a fixed pan called a "saucer," just a little larger than the revolving pan, from which it is conveyed in little buckets attached to an endless and continually moving band, to a platform above the moulding machine, from which it is fed by a shoot into the moulding machine.

The machine used for moulding, or more properly speaking pressing, bricks, on the dry clay system consists of two main movements as follows :—

(1) An arrangement for filling the moulds with the prepared clay, as delivered by the shoot from above.

(2) An arrangement for compressing with great force, the clay into the mould, and so forming the brick.

The movement for filling the clay into the mould, also, at the same time, pushes the last pressed brick from the mould on to a table clear of the pressing heads. Most of the machines in use make two bricks at a time, but some kinds make three bricks at once.

The machine as a whole is in every case, driven by the power from the steam engine conveyed by belting, and the circular motion so obtained is transformed into the movements, by means of cranks and cambs. There are of course variations in detail in the machines by different makers, but the foregoing will, it is hoped, give a good idea of the principle of a dry clay pressing machine.

The bricks, as they are pushed from the moulds, are removed in barrows, directly to the kilns, and stacked therein, and are in a very short time burnt. It will be noticed that a very short period elapses from the time the clay is filled into the trollies in the pit, until it is stacked in the kiln in the form of bricks ready for burning ; and in this particular the dry clay process, presents a marked contrast to the wet-clay process for in the case of the latter the bricks have to be dried before being put in the kiln. Again in the dry clay process, there is no kneading whatever, for the clay is ground up in an almost dry state (there being but very little water at any time put in the grinding pan) and is pressed into the form of bricks rather than moulded.

165. Brick Burning.—In a previous article it was noted that, to make a good brick, proper burning was just as important as a suitable clay composition, and such is indeed the case, for, whilst good clay may be spoilt by bad burning, it often enough happens, that poor, and troublesome clay, is turned into good bricks by the exercise of care, and skill with the burning process. The cost of production is also largely affected by the method of burning. Brickmakers seem to have recognised these points, and have almost departed from the old fashioned "Clamps," and open kilns ; and closed kilns on the continuous principle are almost universally adopted.

166. A Clamp is formed by making a foundation of burnt bricks, and then stacking the raw bricks in courses with a layer of breeze between each course, the outside or casing being generally formed with burnt bricks. During the stacking of the raw bricks, flues, filled with breeze, are formed about five or six feet apart, all over the "Clamp." These flues are connected with "live holes," about 9″ x 9″ in cross section, which run right across the clamp. The stack, or clamp, therefore contains distributed throughout it, enough of fuel to burn the bricks ; and when everything is ready fires are started in the live holes, and continue until the whole of the fuel is consumed, by which time the bricks are supposed to be burnt. Burning by this method is very unsatisfactory, for the bricks are not uniformly affected by the fire, and consequently a difference occurs in the quality of the bricks from the various parts of the Clamp.

In cases of temporary demand, in outlying districts it often happens, that Clamp burning is the only method possible of adoption. It is therefore just as well to be acquainted with particulars as to how to proceed and this information can be obtained in detail form Mr. Dobson's excellent book "Brick and Tile Making."

167 Open Kiln.—An open kiln is a roofless building, rectangular in plan, with large openings at each end, and "fire holes" about 3′ 6″ apart along the sides ; the walls being of a substantial thickness, and built with burnt bricks. The process of burning in one of these open kilns is as follows :—

The kiln is completely filled with the raw bricks, which are so stacked as to leave access by the fire to as much as possible of each, and the openings in the ends are filled up with burnt bricks, and sealed with clay. Fires are then lighted in the

fire holes along the sides, but the temperature is gradually raised during the first two days so that the moisture in the bricks may be slowly dispelled. As soon as the bricks are relieved of the contained moisture, the temporary roof of iron, etc., put on while stacking the bricks, is removed, the fires are set fully going, and the temperature is raised to a very high degree. It takes about six days from the time of "lighting up" to fully burn the bricks to a condition of hardness, after which the fires are ceased to be fed and the fire holes are partially stopped up to prevent the cold air entering too freely. Two additional days are allowed for cooling, and the bricks are then ready for removal from the kiln.

As in the case of clamp burning, though of course not to such great extent, difference in quality occurs, for the bricks are by no means equally burnt throughout the kiln. A great waste of heat also takes place in these kilns owing to the fact, that the draught has an outlet over the whole top of the kiln ; and for the same reason the fuel is not fully consumed, as can be easily understood by anybody who has seen the dense black smoke issuing from these kilns. Open kilns are built to contain from 80,0 0 to 1' 0.000 bricks.

168. Closed Down Draft Kilns, which are a great improvement on those of the open kinds described in the last article, have a permanent roof of brick, arched after the fashion of a barrel vault. The ends are also built up, permanently, to a greater extent than in the case of the open kilns, the openings therein approximating more nearly to what may be called doors. Fire holes are made along the sides in the same manner as in the case of the open kiln, but the draft is arranged in a better and altogether different plan, as the following will serve to show :—

Baffle walls built about a foot wide, parallel to the side walls, and reaching nearly to the roof, cause the draft to have an upward direction until near the top of the kiln, after which the direction is downwards through the bricks to be burnt, and under the floor by a flue which is connected with a smoke stack. In these kilns the heat is more equally distributed over the contents than in those on the open plan, and consequently the colour is fairly uniform and the degree of hardness more nearly constant. Again this arrangement of draft provides for the retention in the kiln of the heat, from a given quantity of fuel, for a much longer time, so that more work is got out of the heat.

There are many kinds of patent kilns, the special features of which are improvements in one way or another on the simple principle of the down draft kiln, and some are so well designed as to burn very good facing bricks uniform in color. Most of the splendid double-faced bricks used in the Australian provinces are burnt in these kilns.

169. The Continuous Kiln is certainly a remarkable improvement on all earlier forms of kilns, and is the conspicuous feature of modern brick manufacture. In almost every brickyard of any importance, there is to be found a continuous kiln with an output capacity of from 100.000 to 240,000 per week. The kiln made on the arrangement as patented by the inventor, after whom it is called, is decribed in the following article.

170. The Hoffmann Kiln is a massive brick circular shaped building with a high smoke stack in the centre, and roofed with light timbers and galvanised iron. Inside a large arched chamber like a railway tunnel is formed parallel to the outside, that is to say, it is annular in plan. This continuous tunnel is subdivided crosswise into compartments or chambers, usually 12 in number. Each of these chambers is connected with the central flue leading to the smoke stack, and is fitted with arrangements for regulating or cutting off the draft by means of dampers. An arched opening to each chamber is also made in the outside of the kiln. The process of stacking the raw bricks, burning, and removing those which have been burnt, goes on continuously at the same rate, and together with the action of the draft may be described as follows :—

Let it be supposed for the purposes of description, that a 14 Chamber kiln is under notice. The external archways of two Chambers are open ; all the others are bricked up. Let these two Chambers be called Nos. 14 and 1 respectively. Raw or green bricks are being wheeled into, and stacked in No. 14. Cool burnt bricks are at the same time being wheeled out of No. 1. The fuel is being supplied into and the fire is at its greatest temperature in Chambers Nos. 7 and 8. The only partition is between Nos. 13 and 14 ; and the only flue open to the smoke stack is

that from No. 13. The course taken by the current of air is therefore as follows :— It enters at opening in Nos. 14 and 1 and is drawn through the chambers Nos. 2, 3, 4, 5, and 6 to the fire, its action as it passes over the bricks just burnt is to cool them, and it becomes quite hot before it gets to the fire. The hot gases, and fumes as they leave the fire are drawn towards the only outlet viz :—by way of the open flue in No. 13. These hot gases have therefore to pass through the Chambers Nos. 9, 10, 11, 12, and 13 which contain bricks *to be burnt;* and it consequently warms, and drys them ready for the fire—bricks for instance in No. 13 will be just getting the hot gases and the moisture in them will be leaving in form of steam, and as each Chamber is nearer the fire the bricks will be hotter, and nearer the firing temperature. From the foregoing it will be seen that very little heat is lost, while the combustion is nearly perfect, for the fuel is supplied in the form of small coal through holes in the roof of the tunnel, and it is no sooner dropped among the red hot bricks than it is in a state of fierce combustion. By the time that No. 1 Chamber is emptied the filling of No. 14 is completed, the partition is made, at the end of No. 14 instead of at No. 13, and the fire travels on one Chamber ahead, and so on goes the process. The partitions were originally iron shutters which were lowered and raised from the top as required, but in some of the later kilns the partitions are simply made with brown paper, or some such light material pasted over the bricks to stop the draft. The light partition is easily destroyed by the draft and heat, when the flue in the Chamber ahead is opened.

171. THERE ARE, HOWEVER, MANY OTHER KINDS OF CONTINUOUS KILNS in operation, but all are more or less based on the principle of the Hoffman. A kiln much in use about Sydney (New South Wales), is rectangular instead of circular in plan, and the continuous chamber consists of two straight tunnels built side by side with the flue leading to the smoke stack in between them. Small openings or archways at each end connect the tunnels and provide for continuity of draft. Another difference,which is also an improvement,is that thereis a flue to the smoke stack from each side of each chamber instead of as in the Hoffmann only one from, the inside.

172. THE CONTINUOUS KILN as it is at present is only useful for burning common bricks, for, as pointed out before, the colour is very bad and the shape is not altogether as good as is to be desired, whilst a source of some trouble in the patent kiln is the "steaming," as despite all care the bricks are sometimes rendered into "slush." The great feature of the continuous kiln is, however, to be found in the cost of operation. In the old kiln it costs about 8s. 6d. per 1000 to burn, and in the continuous only about 2s. 6d. per 1000 to burn; so that it may at once be seen that a great saving is effected, and in this period of "low cost" this counts above everything.

173. CLASSIFICATION AND QUALITIES OF BRICKS.—Bricks are classified in accordance with the methods of manufacture as follows :—

(1) *Sandstocks* or hand made.
(2) *Plastic* Machine made.
(3) *Dry pressed* Machine made.

These classes are again sub-divided as regards quality :—

(*a*) *Callows* or under burnt bricks.
(*b*) *Clinkers* or misshapen and overburnt bricks.
(*c*) *Ordinary* good common bricks.
(*d*) *Picked* or the best among the common ones.
(*e*) *O.K.* or open kiln bricks.
(*f*) *Double pressed* or those which are specially made (generally by the plastic process), twice pressed and specially burnt.
(*g*) *Enamelled Bricks.*

174. CALLOWS are generally bought at a low price and used for interior walls in construction of a poor character. It is, however, needless to say that such bricks should on no account be used in building work, for they have a tendency to crumble to pieces, and they also hold moisture and so make damp walls.

175. CLINKERS are, like callows, to be purchased at a low price, but their most serious defect is in their bad shape. They are usually used for foundations and for rough paving. This kind of brick is got from around the "fire holes" in the kiln, and their ill shape is due to the overpowering intensity of the heat at these places.

176. ORDINARY COMMON BRICKS are those, either hand made, wire cut, or dry pressed. which are of the average quality turned out nowadays. As these bricks are used for the body of the building in most cases, every care should be taken to see that they are of good quality. A clear ringing sound should be given out when two are clapped together. A broken section should show a partial vitrification of the mass ; and a sharp instrument, such as a pocket knife, should make no impression.

Tests should be made, when selecting bricks, to ascertain the power of resistance to compression, and also to determine the percentage of water absorption. A common brick to be of good quality should stand at least a pressure of 1120 lbs. per square inch on it ; and should not absorb more than 6 °/₀ after being for 24 hours immersed in water. In addition to these qualities the brick should be regular in shape and have sharp edges. Common bricks are burnt mostly in the continuous kilns, but in the case of sandstocks the burning is done in open kilns.

177. PICKED BRICKS are the best of the common ones, and should possess beyond question, the qualities described above. As a matter of fact, to get good ordinary bricks it is necessary to specify them to be "picked," otherwise a fair proportion of the more presentable clinkers and callows will be put in.

178. O.K. OR OPEN KILN "GOOD" BRICKS.—A very good kind of common brick is made by the dry process and burnt in the old fashioned kilns. These O.K. bricks, as they are called, are much used for facing purposes where a double pressed would be too expensive. The only point which is an improvement on the continuous kiln brick is, of course, the colour which can be any of the shades of red or other tints.

179. DOUBLE PRESSED BRICKS are made with the greatest care, and are used for such purposes as facing bricks for the best class of buildings and for sanitary work. They are mostly made by the plastic process, but some of very good quality are made by dry pressing. As their name implies they are again pressed after being taken out of the moulding or wire cutting machine. They are burnt with special care in the down draft and cupola kilns, as colour in this class is a matter of the greatest importance. A good double pressed brick should possess in a greater degree all the qualities enumerated in article 176. The resistance to compression should at least be 2000 lbs. per square inch, and the water absorption not more than 3 °/₀. The opposite faces should be perfectly parallel, the edges should be sharp and unbroken, there should be no cracks showing, and there should be no variety of colour or size throughout the particular quantity required. Double pressed bricks such as described are easily enough obtained in the Australian cities, and should be used for important works, for they are practically imperishable. A much less durable kind of double pressed brick of light red and buff tints is much used on account of the soft tone of colour effect obtained ; but they are by no means so durable.

180. THE ENAMELLED BRICKS are very expensive and consequently are sparingly used. For such purposes as linings of Lavatories and light areas they are however indespensible. The body of this kind of brick should be as good as the best double pressed and the enamel should be free from cracks.

181. THE FOLLOWING TABLE compiled from the text Book at the Department of Public Works is interesting as indicating the water resisting properties of the local bricks. The selection from among a great number has been made in a careful manner with a view of obtaining a fair average of the building bricks. The samples were dried and soaked in water for 24 hours.

TABLE XII.

Showing absorpton of water by different Varities of Bricks made in Sydney District.

No.	Locality.	wt. recd. lb.	wt. recd. oz.	wt. dried lb.	wt. dried oz.	wt. wet. lb.	wt. wet. oz.	Per cent. perosity.	Dimensions in inches.
1	Petersham, Double Pressed.	8	$7\frac{1}{4}$	8	$7\frac{1}{4}$	8	12	3·51	
2	Petersham, Double Pressed.	8	$1\frac{1}{4}$	8	1	8	$6\frac{3}{4}$	4·51	$9 \times 4\frac{3}{8} \times 3$
3	St. Peters, Common.	8	0	8	0	8	$7\frac{3}{4}$	6·06	,, ,, ,,
4	St. Peters Common.	9	$1\frac{1}{4}$	9	$0\frac{3}{4}$	9	8	5·01	$9\frac{1}{4} \times 4\frac{1}{4} \times 3$
5	Surry Hills, Common.	8	1	8	1	8	$12\frac{1}{2}$	8·92	$8\frac{3}{4} \times 4\frac{1}{4} \times 3$
6	Hurstville, Common.	8	$4\frac{1}{4}$	8	$4\frac{1}{2}$	8	12	5·68	$9 \times 4\frac{1}{2} \times 3$
7	,, ,,	4	$8\frac{1}{4}$	4	8	4	14	8·33	,, ,, ,,
	,, ,,	4	$9\frac{1}{2}$	4	$9\frac{1}{4}$	4	$15\frac{1}{2}$	8·53	,, ,, ,,
	,, ,,	4	13	4	12	5	$2\frac{3}{4}$	8·88	,, ,, ,,
8	Merrylands, Common	4	$2\frac{1}{4}$	4	$1\frac{3}{4}$	4	$7\frac{1}{4}$	8·35	,, ,, ,,
9	,, ,,	8	13	8	13	9	13 1/3	11·70	,, ,, ,,
10	,, ,,	9	2	9	1	9	$14\frac{1}{4}$	9·14	,, ,, ,,
11	Surry Hills, Common.	7	$10\frac{1}{2}$	7	$10\frac{1}{4}$	8	$6\frac{1}{4}$	9·8	$8\frac{3}{4} \times 4\frac{1}{4} \times 3$ 3/16
12	,, ,,	8	$3\frac{1}{2}$	8	$2\frac{3}{4}$	8	$10\frac{1}{4}$	5·7	,, ,, ,,
13	,, ,,	7	$12\frac{1}{4}$	7	$12\frac{1}{4}$	8	$7\frac{1}{2}$	9·05	,, ,, ,,

Specimens Nos. 7 and 8 were broken into halves prior to being tested.

TABLE XIII.*

Shewing Crushing Strength of Bricks Tested as Received without Preparation.

No.	Description.	Crushing Force per sq. in. in lbs.	Crushing Force in lbs.	Total Force to Crack in lbs.	Area Exposed in sq. inches.	Size in Inches.	Remarks.
1	White	2026	28500	23000	14 1/16	$4\frac{1}{2} \times 3\frac{1}{8}$	Tested with ends bedded in sheet lead
2	Blue	2747	34000	—	12 3/8	$4\frac{1}{8} \times 3$	
3	Red	746	10500	—	14 1/16	$4\frac{1}{2} \times 3\frac{1}{8}$	
4	Yellow	2086	24000	—	$11\frac{1}{2}$	$4\frac{3}{4} \times 3\frac{1}{4} \times 1\frac{5}{8}$	
5	White	4305	38750	31000	9	$4 \times 3 \times 1\frac{1}{2}$	
6	Blue	2696	30000	—	$11\frac{1}{8}$	$4\frac{1}{4} \times 2\frac{3}{4} \times 2\frac{1}{2}$	
7	Blue	2818	31000	10000	11	$4 \times 3\frac{1}{4} \times 2\frac{1}{4}$	
8	a 1	1537	20750	17500	$13\frac{1}{2}$	$4\frac{1}{2} \times 3$	Common Bricks.
9	a 2	1592	21500	16250	$13\frac{1}{2}$	$4\frac{1}{2} \times 3$	
10	a 2	1037	14000	—	$13\frac{1}{2}$	$4\frac{1}{2} \times 3$	
11	b 1	1131	14000	—	12 3/8	$4\frac{1}{2} \times 2\frac{3}{4}$	
12	b 2	1939	24000	19000	12 3/8	$4\frac{1}{2} \times 2\frac{3}{4}$	
13	b 3	1373	17000	13250	12 3/8	$4\frac{1}{2} \times 2\frac{3}{4}$	
14	c 2	1238	16250	15000	$13\frac{1}{8}$	4 3/8 x 3	
15	d 3	1371	18000	15250	$13\frac{1}{8}$	4 3/8 x 3	
16	e 1	1352	17750		$13\frac{1}{8}$	4 3/8 x 3	

* From tests made by Professor Warren.

Specimens Nos. 4, 5, 6 and 7 were radiating bricks for sewers.

182. STRENGTH OF BRICKWORK.—Until quite lately there has been very little information of an accurate character concerning the strength of brickwork. Several well known authorities on the strength of materials have given the loads for brickwork, but the qualities of bricks, and mortars vary so much in different places, that these loads have been from a practical point of view of very little value. For instance in "Civil Engineering" by Professor Rankine the strength of Brickwork in piers is given as about from 800 to 1000 lbs per square inch, but this is of very little use to the Engineer or Architect, without the information as to the standard of brick, and mortar, and the particular kind of brickwork that the load is intended for.

A great amount of information has been gained from the many tests made in different parts of the world on different kinds of bricks, and mortars; but it was not until 1887 that tests were made (at least none have been recorded) to determine if only approximately the difference which exists between strength of bricks, and mortar, and strength of brickwork, built up with same.

During that year a number of important and interesting tests as to the strength of brick piers as compared with individual bricks were made by a Committee of the American Society of Civil Engineers at Watertown in the United States of America.

An abstract of the results (averaged where possible) of the tests is given (by Nos. 5, 6, and 7) in the Table No. XIV. The abstract comprises cases of piers as nearly as possible similar in shape and size so as to facilitate comparison.

These tests showed a great difference between the strength of bricks and the strength of brickwork built up with them. No. 5 in Table XIV. for instance

TABLE XIV.

Shewing Strength of Brickwork.

No.	Kinds of Bricks.	Sizes of Piers.	Average Strength in lbs. per sq. inch of Brick Piers. Age: 3 to 4 Months. Mortar. Lime 1 Sand 2	Age: 3 to 4 Months. Mortar. Cement 1 and 4	Age: 10 Months. Mortar. Lime 1 Sand 2	Age: 10 Months. Mortar. Cement 1 Sand 4	Age: 18 to 24 Months. Mortar Lime 1 Sand 3	Age: 18 to 24 Months. Mortar. Cement 1 Sand 2	Average Strength of Bricks Tested Individually.	
1	Stocks (London)	Cross Section 18″ x 18″	161·93	232·24	195·06	305·66			1310·86	*
2	Gaults		340·97	276·73	336·00	466·35			2834·22	
3	Reds (Leicestershire)	Height, 6′ 0″	478·07	909·22	530·75	784·46			5632·66	
4	Blue (Staffordshire		1155·77	1132·44	1145·82	1283·02			10,906·00	
5	Common	Cross Section 12″ x 12″					1664·4	1991·10	18,200·00	†
6	Face						1726·	2910·00	13,844·40	
7	Bay State	From about 2′ to 10′ high					1241·2	1788·80	11,355·50	

* Tests made by Science Committee of R.I.B. Architects during 1895, at West India Docks, London.

Tests made by Committee of American Society of Civil Engineers during 1887-88, in the United States of America.

Average strength of lime mortar for tests 1, 2, 3 and 4: 1 month, 94·57; 3 months, 135·80; 6 months, 244·53.
" " Cement " " " 1, 2, 3 and 4: 1 " 489·22; 3 " 754·75; 6 " 873·44.

shows brickwork which failed at 1991 lbs per square inch, that was built up with bricks, the crushing strength of which, tested individually, was 18,200 lbs per square inch. They also showed, what was only of course to be expected, that the mortar had a great deal to do with the strength of Brickwork, as will be seen by columns of loads under heads of lime and cement mortar respectively. A feature of importance to be noticed in the results of the American tests is that the common bricks though much the strongest individually made brickwork less in strength, than that built up with face bricks, proving that to have good strong brickwork the shape of the bricks must be good.

As to the actual strength of brickwork the tests did not afford much information, for the piers were of small cross sectional area and the ordinary conditions of bond, a matter considerably affecting the result, were not existing.

The matter does not seem to have had any further attention until during 1895 when a number of tests were made in connection with the Royal Institute of British Architects by a Committee composed of prominent members thereof, aided by the advice and assistance of Professor Unwin.

A most elaborate, and interesting account of the methods of testing, (together with the results minutely recorded) is published in the Journal of the Royal Institute of British Architects, and from this account the results Nos. 1, 2, 3, and 4 Table XIV have been taken. For the purposes of affording the readiest means of comparison, the various results for each kind of pier have been averaged, and moreover, to enable a comparison of strength of bricks with those in the Table XIII., the loads have been converted from tons per square foot to lbs per square inch. Unfortunately some of the piers were built by inserting closers of a soft kind, and the strength of these particular ones were thereby affected to some extent.

Piers were built throughout with proper bricks to replace the defective ones, and tested at a later period, but the results therefrom were of no use for purposes of comparison with any of the other piers for mortar of a much better kind was used when building them. In the table giving a summary of the results which is published in the Journal of the Royal Institute of British Architects the results of the substitute piers are included in the averages with a misleading effect. If they had been built with the improvement of proper closers alone, their inclusion could not have any misleading effect but they were built with mortar of a much better quality, and consequently stood greater loads. In the table compiled by the author the results of tests on the substituted piers are not included the averages taking in the results on the piers with defective closers instead because, it was thought better to have the lesser error due to the bad closers and have results with the same mortar, than the greater error (as far as comparison is concerned) due to better building and better mortar.

It will be seen by the Table that like the American tests they show a wide difference between the crushing strength of bricks individually and brickwork.

The Photographs which were taken at the time of testing have, however clearly shown that the failure is not due to crushing force altogether but to lateral tension and shearing, so that it will at once be evident that when these are the causes of failure the mere crushing strength of a brick cannot represent the strength of a brick pier or wall built with similar bricks. A peculiar feature in connection with the results is that some of the piers at the age of 16 months were not as strong as similarly composed and built piers at the age of 3 or 4 months.

It was expected with a good deal of reason that all would show an increase of strength, and Professor Unwin, in his remarks following the reading of the paper descriptive of the tests, expressed himself as being unable to account for this apparent discrepancy.

183. Terms used in Connection with Brickwork.

Header :—A brick laid with its length across the wall.

Stretcher :—A brick laid with its length along the wall.

Bat :—Portion, such as half or three quarters of a brick.

Closer :—A quarter brick used as at A, Fig. 2 , to make up in courses of headers. *A Queen Closer* is a portion about 9″ x $2\frac{1}{4}$″ x 3″ obtained by halving a brick longitudinally. *A King Closer* is a brick with a corner cut off so as to reduce its head to show as a quarter brick on the surface of the wall.

Frog :—Is the indent on one of the larger faces of the brick. It is made so as to form a key for the mortar, and the brick should always be laid with the face containing it uppermost.

Course :—Is a layer of bricks, such as for instance the upper layer in Figure 20.

Bond :—Is the term given to the method of interlacing or overlapping when laying the bricks so as to cause them to hold to each other, and to spread the weight of each over as many of the others as possible.

The overlapping or bond is provided for by arranging the bricks so that in any one course there shall be none (or as few as possible) of the vertical joints directly over those joints in the course underneath. The distribution of the bricks throughout the wall to bring about this result is a matter of a complicated nature

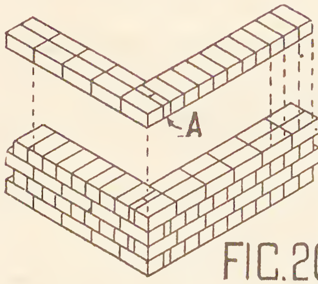

FIG.20

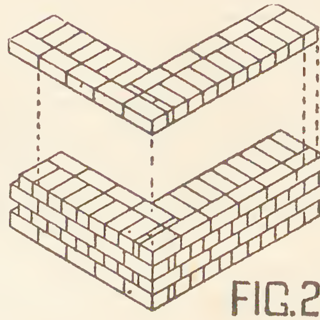

FIG.21

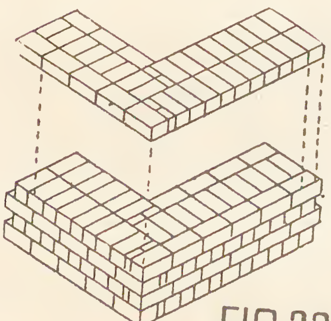

FIG.22

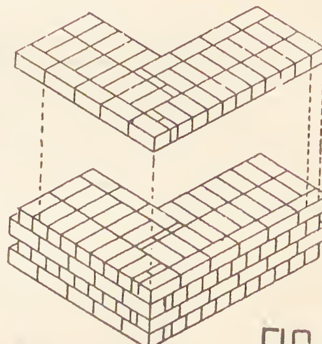

FIG.23

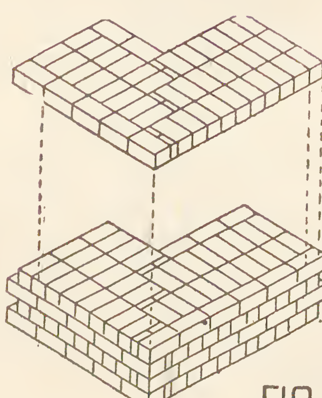

FIG.24

and depends not only on the skill of the layer but also on the shape of the bricks.

184. THERE ARE SEVERAL SYSTEMS OR KINDS OF BOND, but all are based on the same general principle. Those most commonly used are denoted as follows :—

(1) English Bond.
(2) Flemish ..
(3) Colonial ,,

English Bond is considered to be the best, as the breaking of joints is complete. On the surface of the wall this Bond shows courses of stretchers and headers, alternately, for all thicknesses of walls from 9″ upwards.

Figures 20 to 24 are isometric views of English Bond in walls of various thicknesses with corner junctions at right angles. The top course is, in each case, shown as raised up, so as to illustrate the difference between the arrangement of bricks in it, and the course next underneath. It will be seen by the sketches that an external distinguishing feature of this bond, is, that a course of headers occurs between each two courses of stretchers, or in other words, that courses of headers occur alternately.

It will therefore be clear that in any particular thickness of wall the arrangement of the bricks in all heading courses will be alike, and so also will all stretching courses be the same.

The use of closers as providing for the breaking of joints in the heading courses is shown by these sketches.

Figures 20, 21, 22, 23 and 24 represent, respectively, walls 9″, 13½″, 18″, 22½″ and 27″ in thickness.

185 FLEMISH BOND.—In this bond the bricks are so arranged that, on the faces of the walls, stretchers and headers occur alternately in every course. Figure 25, which is an example of Flemish Bond in a 9″ wall, shows, on the face, alternate stretchers, and headers in each course, and also that every header is directly over the centre of a stretcher. This bond is not nearly so strong as English bond for, as shown by figures 25 to 29 which illustrate the arrangements for various thicknesses of walls it is necessary to use a large number of bats, and in addition to this defect, there are also, at certain places, straight joints from bottom to top of the wall. These defects notwithstanding, this kind of bond is much used in the work of a superior character on account of an idea that it looks better than English. Flemish bond is subdivided into two kinds viz : (1) *Double* (2) *Single*. The figures 25 26 27, 28, and 29, represent, respectively, the arrangements for double Flemish bond in walls 9″, 13½″, 18″, 22½″ and 27″ thick. It will be noticed by the drawings that in this kind both sides of the walls are alike—in other words, that every course shows the same arrangement of headers and stretchers on the front as on the back. On this account the bond is called "double." This kind is however the weakest, as straight joints occur at intervals on each side of the wall. To overcome this serious defect, and at the same time to preserve the appearance of Flemish bond on the external face, the bricks are so arranged as to be in Flemish on the face, and in English bond in the remainder of the thickness of the wall. Figure 30 is an example of a 3 brick or 27″ wall in "single" Flemish bond on face and English bond in the remainder. It will be seen by this illustration that in alternate courses on the face the headers are only bats—"snap headers" is the technical term for them. On this account "Single" Flemish bond does not appear at first sight to be as good as "double" but it is really much better, for the straight joints occur at one side only. Limited space does not allow of more than one example of single Flemish bond being given, but the student can, himself, easily draw the other thicknesses of walls by following on the principle as illustrated in the given example viz :—English bond in the body of the wall with just the facing of Flemish, using snap headers in alternate courses.

186. COLONIAL BOND is the Australian name for the arrangement which consists of three courses of stretchers to every one course of headers. Figure 31 illustrates this bond. It is of course only applicable to walls 9″ thick, but in such walls it is as good as any other kind, if properly built, for in the stretching courses there is *half* bond which must give the wall a great deal of strength longitudinally. Bricklayers are, however, in the habit of running up the three courses of stretchers on the face first and then "backing" up with the three courses of inner stretchers. This is done in the interest of speed, but it greatly interferes with the quality of the work, for under such conditions of laying it is impossible to properly flush up the middle

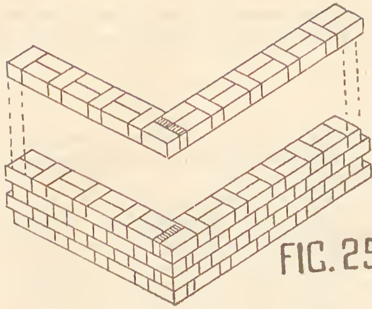

FIG. 25

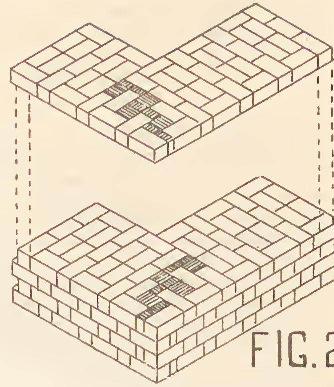

FIG. 29

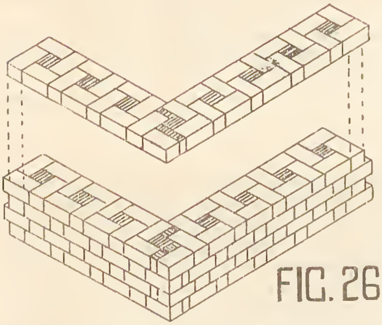

FIG. 26

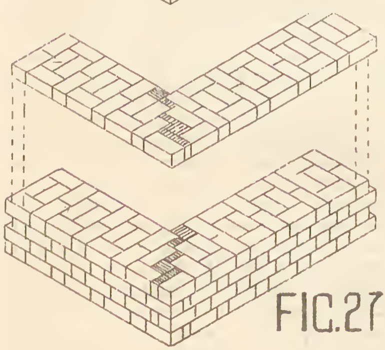

FIG. 27

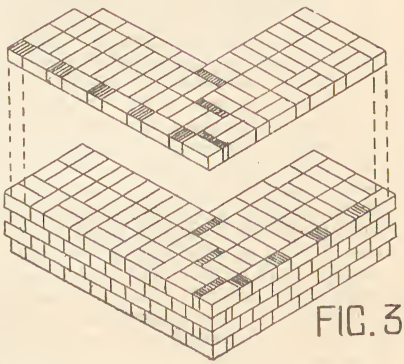

FIG. 30

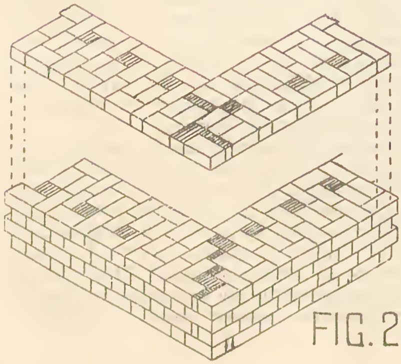

FIG. 28

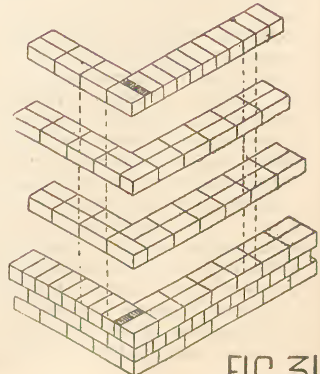

FIG. 31

joint. Colonial Bond is much used in cottages, and small houses, in which walls 9″ thick are about the usual thickness adopted.

187. Raking Bond.—It will be seen by the sketches (Figures 20 to 24) that in English Bond, headers occur in greater number than stretchers. In a 13½″ wall for instance there are only half as many stretchers as headers, and the proportion is greater as the thickness of the wall is increased. Walls of great thickness in English Bond are therefore to a certain extent weak longitudinally. This want of longitudinal tie is remedied by what is called *raking bond*, that is by putting the bricks in diagonally instead of in heading direction between the outside lines of stretchers in the stretching courses. Raking bond is, of course, not possible, nor is it needed in walls less than 22½″ thick.

188. Piers in most cases carry more weight per sq. foot of cross sectional area than walls, and consequently every care should be taken, when building them, to have the best bond. Some examples of bonds for piers are given by Figure 32. It will be seen from the sketches that all piers above 14″ x 14″ are built with closers. The closers are necessary to provide for the breakage of joints to get the bond, but unless of a quality equal to the other bricks, and of proper size, they

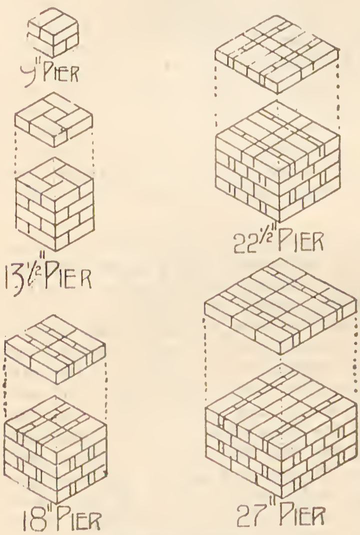

FIG. 32.

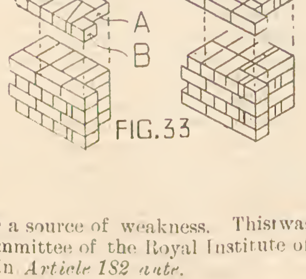

FIG. 33

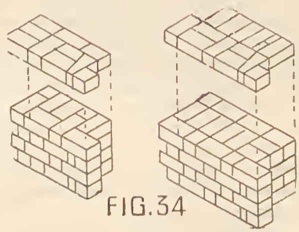

FIG. 34

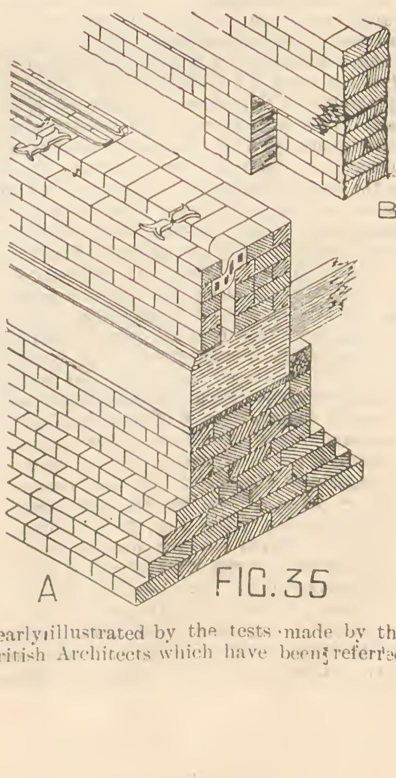

FIG. 35

are a source of weakness. This was clearly illustrated by the tests made by the Committee of the Royal Institute of British Architects which have been referred to in *Article 182 ante.*

189. REVEALS.—Examples of the arrangement of the bricks at the finish of walls round door and window openings are given by Figures 33 and 34. The thickness of the wall (B Fig. 33) in front of the door or window frame is called the REVEAL. and the balance of the thickness of the wall (A Fig. 33) is called the Jamb. Sometimes the inner corner of the Jamb is cut off, or, as it is termed, *splayed*. Of course there is no limit to the variety of Reveal and Jamb, there being so many kinds of door and window frames, and different thicknesses of walls. Figure 33, for instance, shows 4½" reveals in walls 13½". and 18" thick. in English Bond ; and Figure 34 shows similar reveals for the same size walls in Flemish Bond ; but in each case the reveals might have been 9" or the jambs splayed, and so on, the possibility of variation becoming greater as the thickness of the walls is increased. The examples given will, however, serve to indicate, in a general way, the method of finishing round doors and windows.

190. BRICK FOOTINGS.—The matters relating to the design of bearing area and strength of Footings have been dealt with in Articles 66, 67, and 68, ante. so that at this stage it is not necessary to deal with more than the question of Bond. Figures 18 (*Article 81 ante*) and 35, show two cases of offset courses as footings. In Figure 18 each offset is part of a layer composed of two courses of bricks, so arranged, and disposed as to be in the same bond as if in a wall of similar thickness. *A footing* built in such a way, is, therefore, composed of a number of horizontal slices of walls (in English bond), the top slice being 4½" wider than the wall, and every other slice being 4½" wider than the one next above. Such a footing will be strong and will be in accordance with rule laid down in Article 71 ante. In Figure 35 the offsets are parts of single layers of bricks. Those layers, or courses, which are multiples of 9" wide, are composed altogether of headers, while those which are not have one row of stretchers, but it will be noticed that the stretchers are in all cases placed in or near the middle of the footing.

191. HOLLOW WALLS.—It is now becoming a general practice to build external walls, which are exposed to the weather, in two parts with a space between, instead of solid throughout. This is done with a view of preventing the moisture, which is absorbed by the face of the wall, from passing right through. Fig. 35 gives a view of a *hollow* or *cavity* wall. It will be seen that the front part is 4½" thick, and that there is a space 2½" wide between it and the remaining or inner part. This space prevents the passage of any moisture to the inside of the wall, and also acts as a non-conductor thereby preventing the too ready passage of heat, so that the interior of the house is kept cool in hot, and warm in cold, weather. In the cases illustrated by Figs. 35, and 36, the thickest parts of the walls are shown on the inside, and such is the best for, the thinner part, under such circumstances, only, is subject to the action of the weather, whilst the thick part is that which carries the weight of floors and roof and should be on the inside. The front part may therefore be considered as a protecting face wall which as far as strength is concerned has nothing more to do than support itself, and it even has not that much to do, altogether, for the two parts are connected together by bonding bricks or metal ties spaced at frequent intervals. Figs. 35 and 36 show different kinds of connections. The bonding bricks, the manufacture of which it is believed is covered by a patent are made in shape like that shown in Fig. 35, and are composed of the best clay and burned to a thoroughly vitrified state so as to reduce their powers of moisture absorption to a minimum. They are built in at intervals of 2′ 6″ along every third course throughout the wall. These bonding bricks are, where expense is not the chief thing to be considered, the best kind of connection. The metal ties are composed of wrought iron about 1″ wide and ⅛″ thick, at the middle, and shaped like either one or the other of the two examples given by Fig. 35. Of these two kinds the twisted tie is perhaps the best as it does not hold the mortar droppings very readily. A very good, and at the same time cheap, kind of tie is made from ¼″ galvanised iron wire bent S shape shown in Fig. 36. Iron ties should be galvanised to prevent oxidation, and they should be built in at intervals of 2′ 0″ or 2′ 6″ along every third course. The mortar droppings are prevented from getting into the cavity as follows :—A piece of timber the width and length of the cavity is laid on the first row of ties, so as to be just over the cavity. The next three courses of bricks are then laid, and the

batten is removed, and the new row of ties put in. The batten is then put on again over the cavity, and the next three courses built up—and so on until the wall is built. The most troublesome part of the work in connection with hollow walls is the finish round window and door openings, for if this part is not well done the rain will get through, and an ugly dampness will show all round on

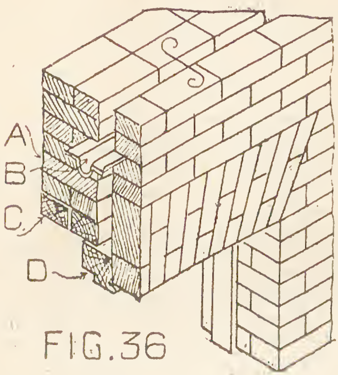

FIG. 36

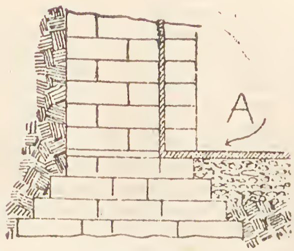

FIG. 39

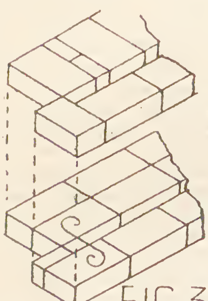

FIG. 37

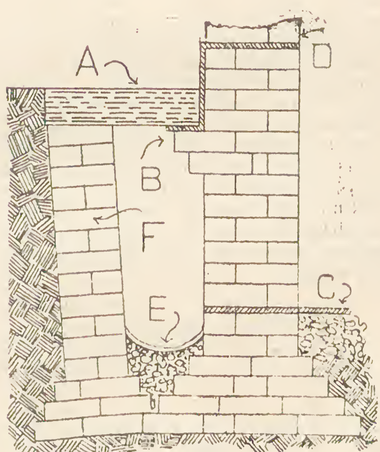

FIG. 40

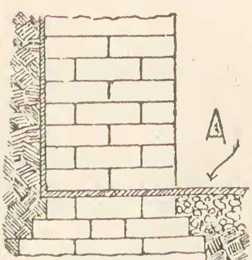

FIG. 38

the nside of the openings. Fig. 37, shows one way of finishing the reveals. The heads of door and window openings may be protected by small lead or gal. iron gutters built in over them as shown at B Fig. 36.

192. DAMP COURSES are built in walls in the following positions :—

(1.) As near the foundations as possible, but not above the level of the lowest floor.

(2.) Along under the coping, when the wall is finished with a parapet.

(3.) Vertically, in the centre, or on the outside, when in the case of a basement wall.

193. THE ESSENTIALS OF A DAMP COURSE are that it will resist the passage of moisture, and be of sufficient strength to stand the weight of the wall resting on it.

194. A DAMP COURSE may be composed of any of the following materials :—

(*a*) Sheet lead.
(*b*) Slates set in cement mortar.
(*c*) Pottery.
(*d*) Asphalt.
(*e*) Patent pliable damp course material.

195. SHEET LEAD is not generally used because it is expensive, but it is quite effective, and is durable, the author having had opportunity of examining courses of this material which were in a good condition after being many years in use.

196. ROOFING SLATES are mostly used in ordinary work. The course is composed either of one or two courses of the slates carefully bedded in mortar, composed of two parts of sand and one part of Portland Cement. In the case of a single course the slates are lapped over each other for about 1½″ or 2″. When a double course is used the lap is half a slate, or in other words the slates are laid in stretching bond like the 4½″ brick wall in Figure 35. There are two important points to be attended to when laying a slate damp course. 1st, Great care is to be taken that the slates are supported everywhere by the bed of mortar, otherwise they will collapse when the superimposed wall is built. The double course of slates allows of the best bedding and is therefore the best. 2nd. Care must be exercised so as to prevent any of the slates being broken, for the damp will rise through the slightest crack. A slate damp course properly laid is sufficiently strong to stand the weight per square foot of all ordinary walling.

197. POTTERY DAMP COURSES are composed of thin slabs or bricks perforated with holes horizontally and burnt to a fully vitrified state. This kind of course is not much used, for it is too thick.

198. ASPHALT DAMP COURSE is laid while in a heated state in the form of a continuous layer about ½″ thick. It makes an excellent damp course, being quite proof against moisture, and its continuity makes it much better than those kinds of courses which are composed of materials jointed together. It is however, necessary to make sure that the right kind is obtained, for there are in the market several kinds which are not strong enough to prevent the weight of the wall from pressing them out. The proper kind is composed of bitumen and limestone grit and becomes very hard. The following table shows the constitution of several kinds of asphalt.

TABLE XV.

ANALYSIS OF ASPHALTS (by MR. W. M. HAMLET).

Kinds.	Percentages.								
	Insoluble Grit.	Soluble Grit.	Total Grit.	Carbonate of Lime.	Bitumen Soluble in Petroleum Spirit.	Bitumen Insoluble in Petroleum Spirit.	Total Organic Matter.	Specific Gravity.	Weight of one cubic foot in lbs.
Trinidad.	47·09	33·59	80·68	25·13	8·50	10·82	19·32	2·138	133¼
Val de Travers.	2·00	87·56	89·56	86·74	7·00	3·40	10·40	2·333	145⅛
Seyssel.	2·50	84·00	86·50	81·90	8·30	5·20	13·50	·312	144

Asphalt is particularly suitable for vertical damp courses. In such cases it is used as follows :—

(*a*) Plastered in two coats each about ¼″ thick on the outside of the basement wall if it is possible to get at it. See Figure 38. It is, however, generally impossible to work from the outside of the wall and one or other of the following methods must be adopted.

(*b*) The outer portion is built first, and then covered on the inner side with two coats of asphalt, after which the inner portion of the wall is built. This method is illustrated by Figure 39.

(*c*) The wall is built with a cavity (about $1\frac{1}{4}''$ wide), which is afterwards filled up with the asphalt while in a hot liquid state.

199. IN THE CASE OF BASEMENTS a layer of asphalt from $\frac{3}{4}''$ to $1''$ thick should be laid on a bed of concrete about $6''$ thick all over to form a floor. The asphalt should be connected without any break whatever (as at A Fig. 39) to the vertical damp course, so as to absolutely disconnect the interior of the basement from anything that would conduct moisture.

200. PLIABLE DAMP COURSE MATERIAL (of which there are several kinds in the market) is convenient to use and is thoroughly effective. These portable damp courses are supplied in rolls of various widths to suit the different thicknesses of walls, and all that is necessary when laying them is to open them out along on the wall and build them in.

201. A DAMP COURSE should be of the full width of the wall on which it is laid, and should extend over bearings of all plates and bearers.

202. AIR DRAINS.—A vertical damp course may, in some instances, be dispensed with by having what is called an air drain, or dry area, on the outside of the wall. Figure 40 will fully explain what an air drain is. F. is a retaining wall built a little distance from and extending along the full length of the building. Stone flags or concrete slabs (A) rest on the retaining wall, and on the corbelling (B) from the building wall. A second damp course should be built in at (D) above and should extend down under the flags. Connections should be made at intervals with a line of drain pipes to carry off the soakage water which may come through the retaining wall.

203. TERMS USED IN CONNECTION WITH ARCHES.—Before describing the various kinds it will be necessary to notice the terms used in connection with arches generally. CENTRE is the name given to the temporary timber frame on which the arch is built. At times arches of large span are erected and in such cases the centres are, on account of the long span and great weight to be carried, structures of a complicated nature. The famous centres used in the building of the arches of the Waterloo Bridge over the Thames at London afford an instance of the complicated character under circumstances of long span and great weight. This type of centre together with other kinds of great centres are illustrated in the "Enclycopædia of Civil Engineering" (Cresy). The builder in ordinary practice does not however meet with more than arches of moderate span, and the centre illustrated in Figure 41 is fairly representative of the kind generally used. The centre, Figure 41, consists of a couple of frames made out of Pine about one inch thick, and cut to suit the form of the arch. The frames are connected along the curved edges by pieces of batten called "*lagging*" shown at B. In most cases the pieces of lagging are nailed on about an inch apart but in the case of an important arch they are kept close together so as to form a continuous curved surface on which the joints of the soffit of the arch are marked out to afford a guide when building the arch. The centre shown is for a span of about $3' 9''$ and would not need any struts, but as the span increases beyond this, struts as at E should be introduced. A centre is held in place by uprights placed against the reveal or jamb, as the case may be, of the opening. Wedges are introduced between the heads of the uprights and the bearing of the centre, as shown at D. The wedges, by their careful withdrawal, allow of the centre being successfully lowered without shock from under the arch. The lowering of the centre from under the arch is called "*striking*." "SOFFIT" AND "INTRADOS" are names given to the under curved surface (c, Fig. 41) of the arch. The outer curved surface (A Fig. 41) is called the EXTRADOS. The inclined surface against which each end of the arch abuts (see B Fig. 43) is called SKEWBACK. The line of the bottom of each skewback is called the SPRINGING LINE and the distance between the springing lines is called the SPAN. The RISE is the perpendicular distance of the highest part (the crown) of the intrados above the level of the springing lines. The blocks or bricks forming the arch are called VOUSSOIRS and the block at the crown is known as the KEY. The HAUNCHES are the parts of the Arch from the

skewback to some distance up towards the crown. SPANDRELS are those parts of the filling in above the arch which lie within the space marked F G and H, Figure 41.

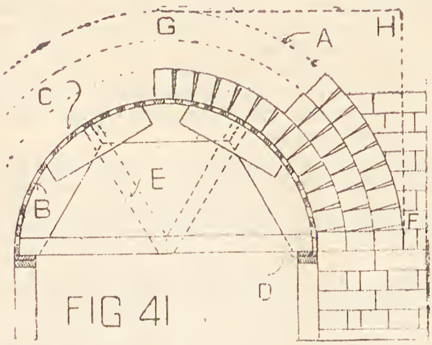

FIG 41

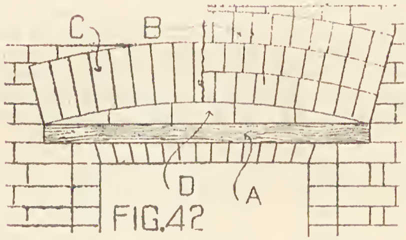

FIG.42

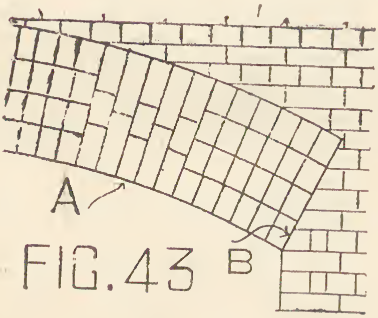

FIG.43

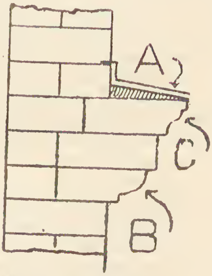

FIG.44

204. IT IS ONLY IN WORKS of a most important character that the bricks are prepared tapered specially to fit the arch and in almost all cases in ordinary practice the bricks are used in their ordinary rectangular shape. To obviate the wide joint that would occur along the extrados if stretchers were used it is the usual custom to build the arch in rings $4\frac{1}{2}''$ wide as shown in Figure 41. This method is not, however, without defect for the rings are only connected together by the mortar and cannot be said to offer a combined resistance to the load on the arch. In cases where an arch has to do important work and where failure would be calamitous to an extraordinary degree binding blocks are put in as at A Figure 43. The building block consists of stretchers bonded together to form a portion which effectually overcomes the isolation of the rings and so effects a bond from intrados to extrados of the arch.

205. **Straight Arch.**—This kind is shown in Figure 36. It is so called on account of the intrados and extrados being straight. This kind is sometimes called a bonded arch because the bricks are shown bonded on the face. As will be seen by the sketch the bricks are tapered and in one half of the arch all the bricks are differently shaped. In consequence of this it is necessary to have the bricks specially moulded, or, if not, soft bricks have to be obtained and rubbed down to the shape required. This kind of arch is well adapted for door, and window. openings, and they have a good appearance. An imitation of this form of arch is sometimes made by using the bricks in their ordinary state on an arch bar of iron about $2\frac{1}{4}'' \times \frac{1}{2}''$, the want of taper being made up in the joint. Again the straight arch is sometimes built with bricks roughly cut to the taper required—the roughness of the edges being rendered partly unnoticable by the pointing.

206. **Semi-circular Arch.**—Figure 41 illustrates an arch semi-circular in shape built in $4\frac{1}{2}''$ rings with ordinary bricks. This is a favourite form of arch and is a very safe kind, for the tendency to spread is not as great as in the other kinds.

207. **Segmental Arch.**—One of the most used forms of arch namely the segmental arch is shown by Figure 43. It of course takes its name from the curve of the soffit. This form of arch should only be used where the abutment is good because (especially when the rise is small) the thrust makes a smaller angle with the horizontal than do those of the other kinds of arches.

208. **Relieving Arch.**—This form of arch as its name implies is used to relieve girders and lintels of the weight of the superimposed walling. Figure 42 shows a couple of kinds. The half marked C is formed with stretchers and is the kind used when the jambs of a window opening are $4\frac{1}{2}''$ deep. That half marked B illustrates the kind used for wider window jambs and also for all kinds of door openings. In all cases the arch should spring from the ends of the lintel or girder so as to be independent of shrinkage or any other change in the lintel. The brickwork (marked D) over the lintel (marked A) is called the core.

209. **Other kinds of Arches** include those which are *semi-elliptical*, *Gothic*, and *horse-shoe*, in form, the construction of which is very similar to those just described, the chief difference being in the method of laying down the curve of form, a matter of geometrical knowledge merely.

210. **Cornices and String courses** built with moulded and other special shaped bricks. In the olden days it was the custom to cut and rub the bricks which were specially prepared for the purpose to the particular shape required and in some of the buildings standing to this day there are examples illustrating the greatest skill on the part of the workers in brick of those days and also affording at the same time examples of very beautiful brick architecture possessing a softness of color effect that is not obtainable at the present day with our hard machine pressed bricks. But, however we may regret the loss of the particular artistic effect, it is impossible to be indifferent to the advantages which our bricks have when considered as to health as well as to durability. The fronts made of such soft bricks must have been damp and now-a-days they would not find favour. As mentioned in Article 179 ante the modern double pressed bricks are so compact and hard as to be practically imperishable, so that all chance of cutting and rubbing is out of the question. The bricks for cornices, string courses, etc., are therefore moulded to the special shape required before they are burned so that the surfaces are just the same as those of the plain bricks. When carefully made, as they generally are, and properly laid they are just as effective, as far as mouldings are concerned, as the rubbed and guaged. A *Splay brick* is shown at A Figure 54. Splay bricks are used for tops of base courses, chimney stacks, cornices, etc.

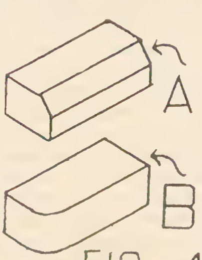

FIG. 45

Bullnosed bricks (one is shown at B Figure 45) are made for jambs of doors, cornices of buildings and parts of mouldings. A section of a small cornice, composed of two courses of moulded and one course of plain bricks is shown by Figure 44. The tops of all cornices and string ourses should be weathered, that is inclined downwards towards the outer

edge, with cement, and in particular work the top should be flashed with lead as at A Figure 44. In the case of ornamental fronts some or all of the rings of the arches are built with bricks moulded on the outer ends.

211. Fireplaces and Flues.—The arrangement of the flues from the various fireplaces in a house is a matter requiring skill and care, and is a most important part of the bricklayer's work for, if badly designed or carelessly built, they are the cause of much discomfort and ill-health. The sketch Fig. 46 is intended to illustrate the various details connected with fireplaces and flues. Mostly the fire-place and its flue or flues between the floor and ceiling of a room are contained in a projection which is called the "Chimney Breast"; and the small piers or parts of the Breast which are on each side of the fireplace are called the "Jambs." In the sketch, Fig. 46, the space for the fire is shown with an arch over it supported on an arch bar, which may be $2\frac{1}{2}'' \times \frac{1}{2}''$ wrought iron. Fireplace arches are, however, sometimes built with a good rise, indeed often enough they are semicircular in form and consequently do not need bars. As will be seen by the drawing the opening above the fireplace is gradually diminished until it becomes of the same size as the flue proper. This part from the top of the fireplace to the flue is called the "Funnel" (marked D on the drawing). The oversailing of the brickwork to form the funnel produces what are called "Wings" (marked C and F on the drawing)—the one that oversails the most (C on sketch) being called the "Gathering" wing. It will also be noticed that the funnel is not led directly into the flue, but is caused to bend towards one side first. This bend improves the flue by preventing down draughts. A bend just over the funnel is, however, only necessary when the fireplace is in the storey just under the roof, for in the cases of those flues which come from lower fireplaces there are bends which, from a constructive point of view, are unavoidable, but which also serve the useful purpose of preventing down draughts. In the particular example given by Fig. 46 there are shown flues which lead from fireplaces in lower stories. These flues are brought up through the jambs and thence upwards as shown. Such is the general arrangement where fireplaces are one below the other (as they usually are) in the different stories of a building. The partitions between the flues are called "Withes," see H. Fig. 46. It is essential to have the withes very carefully built so as to prevent any openings however small between the flues, for if there is any leakage of draught there will surely be a smoky flue. A portion of the front of the chimney breast, Fig. 46, is shown as removed with a view of illustrating the way that the brickwork is built to form the various flues, etc. The bond is, of course, a matter which depends on the curves and number of the flues, so that the principle underlying it can be best described as the getting of as much tie or breaking of joints as possible. In ordinary work it is the custom to build the Breasts with the space between the $4\frac{1}{2}''$ next to the outermost flue and the $4\frac{1}{2}''$ of the outer sides of the Breast hollow, so producing what is called a "Pocket." It is, however, much better to build the breast solid. Each fireplace should have a separate flue, and the longer the flue the better the draught. It is to be remembered that the draught

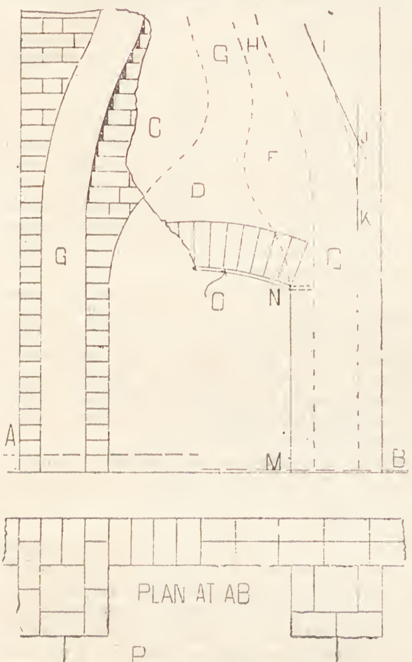

FIG. 46

upwards in the flue is caused by the ascent of the heated air from above the fire, consequently it is important to prevent the ingress, over the fire, of more cold air than can be heated. In other words the flue will not act if too much space exists between the top of the fire and head of fireplace. Neglect of this point has produced more smoky flues than any other cause. The outlet of the flue, that is the top of the chimney stack, should be above the highest part of the building or nearly adjacent buildings. If not, the eddies produced by the walls or roofs will cause down draughts. Trees near to chimney stacks are very often the cause of smoky flues, for the same reason. Flues for ordinary room fires are 9″ x 9″ in cross section, but for large fires, as for instance in the case of kitchens, they are made 14″ x 9″. Flues 14″ x $4\frac{1}{2}$″ have been built, but the size (though allowing of a flat breast) is awkward. The bends in the flues should not be too sharp, but should be gradual and regular (see I. J. K. Fig. 46. Any angle under 130° is too quick. During the building there is danger of the flues at the bends being made too narrow, so that special care is necessary at these places. It is a good plan to employ a chimney-sweep to put his brushes through the flues prior to the taking over of the building from the builder, so as to discover in time any stoppages or defective bends.

212. **Flues** should be rendered with lime, or Portland Cement, mortar and finished quite smooth; and with a view of preventing damage by fire it is necessary to take care that timber or other inflammable material is not built in nearer than at least $4\frac{1}{2}$″ to the inside of the flue.

213. **Hearths.** The stone slabs about 6″ thick which were at one time almost always used for the hearths, or floors of fireplaces, are now almost entirely superseded by concrete. In the case of ground floor, or basement, fireplaces, the concrete is laid on to a filling of stone spawls which is kept in place by a brick hearth wall, and for those floors where such a method cannot be adopted, as for instance upstair floors, the concrete is put into a case or box formed with timber in the floor. In common building the concrete is rendered on the top and trowelled off to a smooth finish, but in work of a first-class character the surface is generally formed with glazed hearth tiles, 6″ x 6″ in size, which admit of artistic treatment, and make a sound imperishable top surface.

214. **Essentials of Good Brickwork.**—To have good brickwork it is essential that the bricks shall be well shaped, and of proper size, that they shall be laid square with the face of the wall, and perfectly level, and also that the mortar joints shall be well filled and neither too thin or too thick. If these conditions are fulfilled the joints will be regular, the courses will be horizontal, and the "perpends" will be well kept. Keeping the "perpends" means that similar joints of similar courses are arranged one above the other in perpendicular lines. The bricks should be perfectly rectangular in shape, while the size depends upon the thickness of the joint adopted. By reference to Art. 122 *ante* it will be seen that joints about $\frac{1}{4}$″ thick make (other things being equal) the strongest brickwork; the thickness of bricks is generally 3″, but this is not of much consequence, the length and width being the dimensions which affect the bond. To have joints $\frac{1}{4}$″ thick the bricks should be 9″ long and $4\frac{3}{8}$″ wide, as can be easily demonstrated by drawing, full size, a portion of a brick wall. If the joints are to be $\frac{3}{8}$″ thick the bricks will require to be $4\frac{5}{16}$″ wide, and so on. The joints both horizontal and vertical should be well filled up with mortar. It is in this particular direction that most of the harm is occasioned by careless and unscrupulous bricklayers by their neglect to fill up the joints. A wall built with only the outside of the joints filled with mortar cannot be strong, or proof against the weather, so that every attention should be given to the thorough filling of them. The best way to provide for the joints being well filled is to grout up each course with **Grout** or liquified mortar (see Art. 119 *ante*). There is, however, some objection to be raised against the use of grout on account of the weakening tendency of the water added for liquifaction. On this account many engineers and architects avoid using it, and ensure the joints being well filled with mortar from the trowel by constant supervision.

215. **Finish of the Joints.**—Wherever the bricks are to be left exposed the joints should be "struck." This is generally done by running the trowel along the joint pressing it smooth, and finishing it with a slight inclination downwards and outwards. Care should be taken that the inclination is not inwards, for, when

finished in such a way there is a tendency to turn the rain water into the wall and dampness will result. The struck joint is much improved if the lower edge is cut off with the trowel. This is called a "struck and cut" joint. Of course where the surfaces of walls are to be covered with plaster, or cement rendering, the joints are left rough so as to afford a "key" for the plaster or cement. *Tuck pointing* is another way of finishing brickwork joints and is done after the wall is built as follows :—The mortar is raked out to a depth of about 1″ and the space is refilled with a mixture composed of cement and sand, coloured to match the tint of the bricks. This filling is made flat and flush with the face of the wall. The joints are then lined out with a narrow white line (about ⅛″ wide) formed of lime putty. Tuck pointing, though generally adopted, is not to be recommended, for it is only too often made the means of covering up defective brickwork—the white lines being run over the faces of the bricks to remedy faulty "perpends," and ugly thick joints are disguised by the filling, thus rendering bad work unnoticeable.

216. Thickness of Brick Walls.—The following tables, and notes relating thereto, are taken from the "City of Sydney Improvement Act." They will be found to contain information regarding all ordinary cases of building, and may be followed with safety and economy.

TABLE XVI.

Showing thickness of external and party walls of Dwelling Houses.

Height up to 100 feet.	Length up to 45 feet. One story ... 27 in. Two stories ... 22½ ,, Three stories ... 18 ,, Remainder ... 13½ ,,	Length exceeding 45 feet. Wall to be increased in thickness in each of the stories below the uppermost two stories by 4½ in. (subject to provisions respecting distribution in piers).
Height up to 90 feet.	Length up to 45 feet. One story ... 27 in. Two stories ... 22½ ,, Three stories ... 18 ,, Remainder ... 13½ ,,	Length exceeding 45 feet. Same as above.
Height up to 80 feet.	Length up to 45 feet. One story ... 22½ in. Three stories ... 18 ,, Remainder ... 13½ ,,	Length exceeding 45 feet. Same as above.
Height up to 70 feet.	Length up to 45 feet. One story ... 22½ in. Two stories ... 18 ,, Remainder ... 13½ ,,	Length exceeding 45 feet. Same as above.
Height up to 60 feet.	Length up to 45 feet. Two stories ... 18 in. Remainder ... 13½ ,,	Length exceeding 45 feet. One storey ... ... 22 in. Two stories ... 18 ,, Remainder 13½ ,,
Height up to 50 feet.	Length up to 30 feet. One story .. 18 in. To below topmost story ... 13½ , Remainder ... 9 ,, Length up to 45 feet. Two stories ... 18 in. Remainder .. 13½ ,,	Length exceeding 45 feet. One story ... 22 in. One story ... ... 18 ,, Remainder .. ... 13½ ,,
Height up to 40 feet.	Length up to 35 feet. To below topmost story ... ... 13½ in. Remainder ... 9 ,,	Length exceeding 35 feet. One story .. ... 18 in. To below topmost story 13½ ,, Remainder ... ... 9 ,,

Height up to 30 feet.	To below topmost story ... ... 13½ in. Remainder ... 9 „	
Height up to 25 feet.	Length up to 30 feet. If two stories ... 9 in. If more than two stories to below topmost story 13½ „ Remainder ... 9 „	Length exceeding 30 feet. To below topmost story 13½ in. Remainder .. ... 9 „

"If any storey exceeds in height sixteen times the thickness prescribed for the walls of such story in the above table, the thickness of each external and party wall throughout such story shall be increased to one sixteenth part of the height of the story; but such additional thickness may be confined to piers properly distributed, of which the collective widths amount to one fourth part of the length of the wall."

TABLE XVII.

Showing thickness of walls of Public Buildings and Warehouses.

The thickness of walls at the top and for sixteen feet below the top to be 13½″, and the intermediate parts, between base and such sixteen feet, to be built solid between straight lines on each side of wall from base to lower part of the top sixteen feet. For walls not exceeding 30′ in height the topmost storey walls may be 9″ thick.

Height up to 100 feet.	Length up to 45 feet. Base ... ... 27 in.	Length exceeding 45 feet. Wall to be increased in thickness from base to within 16 feet of the top by 4½ in. subject to provision respecting piers.
Height up to 90 feet.	Length up to 45 feet. Base ... ... 27 in.	Length exceeding 45 feet. Same as above.
Height up to 80 feet.	Length up to 45 feet. Base ... ... 22½ in.	Length exceeding 45 feet. Same as above.
Height up to 70 feet.	Length up to 45 feet. Base ... ... 22½ in.	Length exceeding 45 feet. Same as above.
Height up to 60 feet.	Length up to 45 feet. Base ... ... 22½ in.	Length exceeding 45 feet. Base... ... .. 27 in.
Height up to 50 feet.	Length up to 30 feet. Base ... ... 18 in. Length up to 45 feet. Base ... ... 22½ in.	Length exceeding 45 feet. Base... ... ... 27 in.
Height up to 40 feet.	Length up to 35 feet. Base ... ... 13½ in. Length up to 45 feet. Base ... ... 18 in.	Length exceeding 45 feet. Base... ... ... 22½ in.
Height up to 30 feet.	Length up to 45 feet. Base ... ... 13½ in.	Length exceeding 45 feet. Base... ... ... 18 in.

Height up to 25 feet.		Length unlimited. Base... ... ... $13\frac{1}{2}$ in.

"If any story exceeds in height fourteen times the thickness prescribed for the walls of such storey in the above table the thickness of each external and party wall throughout such story shall be increased to one fourteenth part of the height of the story ; but such additional thickness may be confined to piers properly distributed, of which the collective widths amount to one fourth of the length of the wall."

217. TERRA COTTA is a material now much used in connection with ornamental brickwork for fronts and other exposed parts of buildings, and if well designed and of good quality it looks really well. This material makes a logical and harmonious finish for brickwork, and this climate is very suitable for its use. Judging by examples of colonial Terra Cotta it is not too much to say that better material for its manufacture could not be got than that available in the Australian Provinces, and the general use of Terra Cotta in connection with brickwork is only a question of time. It is, however, to be hoped that its general use will not degenerate into the awful abuse of continual repetition of certain stock designs of an alleged ornamental nature which has so characterised the use of cement stucco for architectural purposes. Terra Cotta ornament should be specially designed by the architect, and modelled by hand, for though moulds are all right for plain blocks, and for diapers and such other forms the exigencies of casting prevent the production of pleasing and beautiful designs.

218. The composition of the clay is a matter of great importance, for color and surface are matters demanding much more attention than is the case with the best class of bricks. The body of the Terra Cotta must be partially vitrified, to ensure durability, and the surfaces must be free from all blotches and flaws, and of uniform colour. From what has been written about bricks it will be quite clear that these conditions are difficult to meet. A fairly pure clay with a little iron can be used for Terra Cotta, by adding either sand, ground glass, or burnt clay, to prevent shrinkage. The clay is, however, mostly obtained by judicious mixing of several kinds of clay. The manufacture of Terra Cotta is not carried on in all places in the same way, but the following short description may be taken as a fair illustration of the process. The different kinds of clay after being excavated are weathered by long exposure to the disentegrating effects of the atmosphere, and then separately ground up and mixed with water. Piles are then built up of layers of clay, each layer being composed of a certain kind. Vertical cuts are then made through the pile, thus getting a bit of each layer, and the portions so cut off are ground up and thoroughly "tempered" in pug or grinding mills, after which the clay is ready for moulding. When the shape or design of the block or piece is to be repeated moulds made of plaster are used for shaping purposes, but when only one piece is to be made the modelling is done by hand. After moulding or modelling, as the case may be, the blocks are very carefully dried and then burned, or rather baked, in covered down draught kilns. Undoubtedly one of the most difficult things in connection with the manufacture of Terra Cotta is the prevention of warping and cracking due to unequal shrinkage. As before pointed out, sand or burnt clay is mixed with the clay to prevent shrinkage as far as possible. The blocks are also made hollow so as to reduce the amount of material. Despite these provisions, if the greatest care is not exercised the work will crack when drying, and it requires skilled attention to successfully supervise the drying. Attention should therefore be given when designing that the block will be such as that all its parts will dry at an equal or nearly equal rate.

219. The colour of Terra Cotta ranges from a white to a dark red—the tints mostly are from light buff to light red. With the use of chemicals it is as with bricks possible to obtain almost any colour. It is, however, very unusual to depart from the natural colours of the clay.

220. Terra Cotta is used for bases, skewbacks, corbels, capitals, window and door heads, window cills, copings, jambs, mullions, panels, and in the thousand and one ways that stone may be used as dressings for brickwork. The parts or blocks are built in, in much the same way that stone is, and the joints are pointed with cement mortar, which is generally tinted to match the colour of the Terra Cotta.

CHAPTER VIII.

BUILDING STONES.

221. Classification of Rocks.—The rock formations from which the building stones are obtained may be classified under three heads, namely :—

(1) Igneous.
(2) Sedimentary.
(3) Metamorphic.

222. Igneous Rocks are those which have been forced up into or through the crust of the earth in a molten or plastic state by the action of heat. This group is divided into sections as follows :—

(a) Orthoclase Rocks.
(b) Plagioclase ,,
(c) Olivine ,,

223. Orthoclase Rocks.—In this section the principal silicate is orthoclase or potash feldspar, which occurs either in its common white or pink form or as *sanidine* (that is, in a glassy condition. Hornblende, mica, and apatite, occur commonly. Free quartz in blebs or in definite crystals also occurs in many of the rocks. Of the igneous group these rocks contain the most silica. Granite, Syenite, Porphyry, and Trachyte are orthoclase rocks.

224. Plagioclase Rocks.—The rocks in this division of the igneous group contain some variety of lime or soda feldspar and either augite or hornblende. Free quartz also occurs in some of them, but they usually contain much less silica than do those of the orthoclase division. Basalt, Dolerite, and Diorite are plagioclase rocks.

225. Olivine Rocks are comparatively few in number. They consist principally of the mineral Olivine. Augite, Hornblende, and Mica also occur in these rocks.

226. Sedimentary Rocks are those which have been formed by the deposition of some kind of sediment, or detritus, or from the remains of plants or animals. This group contains the largest number of rocks, many of which are of the greatest value in building work. A feature of this class of rocks is that generally they are stratified. The group may be subdivided into three sections, viz. :—

(a) Fragmental or Clastic Rocks.
(b) Chemically Precipitated Rocks.
(c) Rocks formed by the remains of plants or animals.

227. Fragmental Rocks are formed in a mechanical manner from the detritus or sediment from the destruction of the older rocks. Conglomerate, Breccia, Sandstone, and Greywacke are among those rocks which have been formed in such a way. The hard fragments are cemented together with a matrix, and a mass is produced ranging from a loose to a compact body according to the hardness of the fragments and the quality of the cementing medium.

228. Chemically Precipitated Rocks are formed by the precipitation of the mineral matter held in solution by water. Carbonate of Lime, Sulphate of Lime, Chloride of Sodium, Silica, Carbonate of Magnesia, and Salts of Iron are abundantly deposited in such a way. The Oolitic, Pisolitic, and Travertine varieties of Limestone, and also Dolomite and Gypsum have been formed by Chemical Precipitation.

229. Rocks formed by the remains of plants and animals. Very extensive accumulations have been, and are now being formed of the remains of plants and animals. Owing to the fact that Carbonate of Lime is largely secreted by animals in their shells and skeletons, it forms the chief substance in rocks of organic origin. Chalk and Crinoidal Limestone are rocks formed from the remains of animals. The other rocks in this section (coal for instance which is a mineralised vegetation) are of no use in building work and need no notice.

230. METAMORPHIC ROCKS are those which have been changed from their original structure either by heat or by pressure or by both combined. The term is however generally applied to the recrystallisation which sedimentary rocks have undergone through the action of heat and pressure. Marble affords an example of this kind. Originally a limestone formed by organic agency or by precipitation it has been changed into a crystalline structure by the action of heat and pressure due to igneous eruptions through it. The schistose rocks such as Gneiss and Mica Slate are metamorphic, the schistose condition being brought about by enormous pressure and shearing. Clay Slate is another rock which may be taken under the head of metamorphic, because though originally a sedimentary rock its structure has been changed to that of a fissile character by the action of pressure.

231. In the following articles will be found the various building stones described as regards the above classification, and with particulars as to physical qualities, from the builder's point of view.

GRANITE.

232. GRANITE, one of the igneous rocks of the orthoclase section, is a holo-crystalline compound of feldspar, quartz, and mica; the crystals of these minerals being in simple apposition, and large enough to be distinctly visible to the naked eye. The feldspar predominates and is mostly orthoclase, but sometimes feldspars of the plagioclase group are present. In colour the feldspathic crystals are either pink or some tint of red, but sometimes are pale grey, and rarely of a greenish tint. The quartz occurs in the form of colourless or grey crystals; and the mica in bright glistening scales. The greater the quantity of quartz present the more durable will be the stone; but the presence of a large quantity of the quartz makes it very difficult to work. The feldspar crystals should be small and lustrous, for, if they are large and dull, they are likely to be decomposed and consequently a source of great weakness. The mica is the weakest of the ingredients and is very liable to decay. Many other minerals occur in small quantities. Of these iron is very dangerous if in combination with sulphur as pyrites, for decomposition is liable to take place and the sulphur set forth forms into sulphuric acid and destroys the stone. It requires considerable skill to judge as to the probable dura-ability of a granite stone, but the leading points are as set out above, namely, the presence of a fairly large quantity of quartz, and small lustrous crystals of feldspar.

233. PORPHYRITIC GRANITE. Occasionally granite is found in which there are large crystals of feldspar embedded in the much less defined and smaller crystals of the other constituents. Rock of such a structure is called Porphyritic Granite.

234. SYENITE is a holo-crystalline rock composed of orthoclase and hornblende, and is distinguished from granite on account of the absence (or almost so) of quartz and mica. As the crystals of the hornblende are black or dark green, syenite is of a dark colour, and is consequently not so pleasing as the true granite. In the case of orthoclase, quartz, mica, and hornblende all being present, the rock so formed is called Syenitic Granite. This latter kind is usually a dark, compact, and very durable rock.

235. True granite, syenite, and porphyritic granite, are popularly all classed as granite in ordinary building classification.

236. Up to the present in the Australian provinces granite has only been used in a subsidiary way for plinths, columns, and so on, and has, except in rare cases, always been imported from the old countries. It is, however, true, that granite of excellent quality abounds in various parts of Australia, and it only requires that the different quarries, now already opened up, shall be well developed to cause a more general use of this valuable building stone.

237. In New South Wales, granite quarries have been started at Moruya, Montague Island, Tamworth and Trial Bay. That obtained from the Moruya quarries is a grey granite of a durable kind and is well suited for building purposes. An example of this granite can be seen at the General Post Office in Sydney, where it has been used for the columns of the arcades. There are quarries at Harcourt, Beechworth, Mount Eliza, Alexander, Martha, and Blackwood, and at Plenty Ranges, Gabo Island, and Refuge Cove, all in Victoria. Red granite from Gabo Island was used for the columns of the main entrances of the last

extension of the Lands Offices in Sydney. It is a very hard durable stone and has a fine appearance. Red granite is also obtained in Queensland at the Gilbert Gold Fields, while a fine green granite is got at Ravenswood in the same province. In South Australia a good Red Granite is obtained at Port Elliot.

238. The granites usually imported in the forms of finished columns, plinths, pedestals, and base courses are those from the famous quarries of Aberdeenshire in Scotland. A very fine red granite from Peterhead in that County is much valued for columns and has been greatly used in the Australian cities, but a close inspection shows that the red granite from Gabo Island is quite equal to it and has a claim upon those who are using granite stone locally for building purposes. The quarries of Aberdeenshire are prolific in grey granite, and many fine specimens are to be found in some of the leading buildings of our provincial cities.

239. Granite, Syenite, and Porphyritic Granite are very hard to work on account of their great hardness, and it is only in costly buildings that this can be used. These stones are best fitted for a massive style of architecture where the walling surfaces may be left rough or rock faced, and where the only dressed work is that of the plinths, columns and other ornamental parts which may be polished.

240. The following may be taken as representative of the chemical composition of granite and syenite. *Granite* : Silica, 72·07, Alumina, 14·81, Peroxide of iron, 2·22, Potash, 5·11, Soda, 2·79, Lime, 1·63, Magnesia, ·33. *Syenite* : Silica, 59·83, Alumina, 16·85, Protoxide of iron, 7·01, Lime, 4·43, Magnesia, 2·61, Potash, 6·57, Soda, 2·44.

TRACHYTE.

241. TRACHYTE, one of the igneous rocks of the orthoclase division, is of a compact Porphyritic structure and is composed normally of Sanidine (plagioclase sometimes being present) and hornblende, mica, augite, etc. The Porphyritic crystals are usually of sanidine, while the matrix consists mainly of minute feldspar crystallites. In colour these rocks vary from grey and yellow to red brown tints.

242. TRACHYTE is found in all of the provinces, but is seldom quarried for building purposes. A rock very much like trachyte, but which according to the Government Geologist of New South Wales (who has made a careful investigation) is really a syenite, has been found at Bowral in N.S.W. This rock is known in the building trade as trachyte and is a very good stone of a bluish grey colour. It has been used extensively in Sydney, but reason for much anxiety has been caused in several cases where it has been used for columns and piers by the occurrence of serious cracks which have appeared after the stones have been some time in position. The origin of these cracks has not been, up to the present, fully investigated, but among practical men the opinion is held that the cracks are caused during blasting, become larger as time elapses, and so only become visible at a period some time after quarrying. Such may be the cause, or it may be that the damage is brought about by climatic influence. In any case it becomes necessary to carefully examine each block, where the work is of importance, so as to guard as far as possible against failure. An analysis by the mineralogist of the Dep. Mines of N.S.W. shows the constitution of this Bowral "Trachyte" to be as follows :—Moisture at 100 c., ·68, Combined water, 1·52, Silica, 57·14, Alumina, 16·13, Ferric Oxide, 4·69, Ferrous Oxide, 4·00, Manganous Oxide trace, Lime, 3·44, Magnesia, ·63, Potash, 5·07, Soda, 4·87, Phosphoric Acid, ·25, Carbonic Acid, 1·42, Sulphuric Acid, ·30, Chloride Sodium, ·04.

243. The composition, chemically, of Trachyte on the average is as follows :— Silica, 60·0, Alumina, 17·0, Protoxide of iron, 8·0, Magnesia, 1·0, Lime, 3·5, Soda, 4·0, Potash, 5·0.

PORPHYRY.

244. PORPHYRY, also a rock of the orthoclase group consists of large crystals of orthoclase interspersed throughout a matrix which is composed of quartz, and orthoclose intimately mixed.

245. The Porphyry rocks are as a rule difficult to obtain in large blocks and consequently are not generally much used in building work. The more beautiful kinds when polished have a fine appearance and are greatly valued for such purposes as panels and shafts of small columns in architectural work.

246. Australian porphyries, while being fairly plentiful are generally speaking of no particular beauty. At O'Connell Town, near Brisbane, a prophyry of pinkish tint is obtained, and is much used in the latter city. In the Mineralogical Museum at Sydney, there is a specimen of a porphyry from Cowra in N.S.W. It is of a beautiful green tint and will make a valuable stone for use in ornamental masonry work.

BASALT, DOLERITE, DIORITE.

247. These rocks are also of the igneous class but of the plagioclase sub-section. BASALT or bluestone is a dark compact homogenous rock composed of plagioclase, augite, magnetite, etc. ; the structure being such that the component minerals are too minute to be seen by the naked eye. The kind in which the grains of the constituent minerals are coarse or large enough to be visible without the use of a microscope is called DOLERITE. DIORITE or greenstone is closely allied to the Basalts, the main difference being that the mineral hornblende occurs in it and causes the greenish tint that is the characteristic feature in the appearance.

248. Like the Granites the Basalt rocks are very difficult to work and consequently for masonry work they are costly. Again, on account of their sombre appearance, they are far from attractive and are only suited for architectural work of a heavy style.

249. Basalt rocks occur in great abundance in all the provinces, and are extensively quarried more especially for civil engineering works such as roads and bridges. In the city of Melbourne a basalt found in the locality has been greatly used in building work. This stone has also been largely exported to the other provincial cities. In N.S.W. there are quarries at Camden, Goulburn, Cooma, Kiama, Jervis Bay, Mittagong, Liverpool. Bathurst, Parkes, Blayney, Nundle, Tamworth, Armidale, Lismore, Inverell, Hill End, Wellington, Dubbo, Mudgee, etc.

250. BASALT AND DIORITE are composed as follows :—*Basalt* : Silica, 45·00 Alumina, 15·00, Magnesia, 6·50, Lime, 10·50, Soda, 3·50, Potash, 1·50, Oxide of iron and Manganese, 15·00. *Diorite* :—Silica, 53·20, Alumina, 16·00, Potash, 1·30, Soda, 2·20, Lime, 6·30, Magnesia, 6·00, Oxides of iron and Manganese, 14·00.

SANDSTONE.

251. As pointed out in Art. 227 sandstone is a sedimentary rock of fragmental structure, the fragments being grains chiefly of quartz, but sometimes of a calcareous or argillaceous character. The cementing material or matrix may be either of a siliceous, calcareous, ferruginous or argillaceous nature. Mica, glauconite and other minerals occur in proportionately small quantities in sandstones. According to the predominence of the particular mineral, sandstones are classified as follows :—

Siliceous Sandstones.
Calcareous ,,
Argillaceous ,,

Those kinds in which the mica is in comparatively large quantities are called *Micaceous Sandstones.*

252. The best kinds are those which are composed of sharp clean grains of quartz cemented together with a siliceous matrix. Sandstones composed of grains of carbonate of lime and a siliceous matrix, or those with quartz grains and lime matrix, should stand fairly well, but, of course, would not, especially in town atmospheres, be nearly as durable as those of the imperishable quartz grains and siliceous matrix. Stones composed of argillaceous grains or matrix are liable to decay and disintegration, and are seldom used for building purposes.

253. Sandstones may be obtained perfectly white, or in colours, ranging from grey, yellow, brown, red, to dark blue. White stone shows absence of iron and other colouring minerals. Iron is the usual cause of the colour of sandstone. For instance, hydrated peroxide of iron being present causes various shades of yellow,

while the different tints of red are caused by anhydrous peroxide of iron. Bluish colours are caused by phosphate of iron. Glauconite gives a greenish tint.

254. SYDNEY is surrounded with sandstone quarries, from which excellent building stone is obtained. The best known of the quarries about Sydney are those at Pyrmont, from which a fine grained and durable stone of even texture, which turns yellow on exposure, is obtained. Under the microscope a sample of this stone shows the grains to be clean and sharp. and the whole mass appears as bright and lustrous. This stone stands M. Brard's sulphate of soda test fairly well. There are also quarries at Waverley and Marrickville, from which similar stone is obtained. Good stone is also quarried at various other places not far from the city. The chemical composition of Sydney sandstone is as follows :—Moisture at 100 c. ·45, combined water 1·40, silica 87·60, alumina 8·53, ferric oxide ·03, ferrous oxide ·10, lime ·60, magnesia ·29, potash ·28, soda ·45 sulphuric acid ·11, phosphoric acid trace, chloride of sodium trace, soluble silica ·40* The sample giving the above analysis being from Pyrmont. Specimens of excellent sandstones of more or less fine grained texture from Maitland, Ravensfield, Rutherford, Clarence Town, Morpeth, and Paterson, in the Hunter River District, are exhibited in the Mineralogical Museum at Sydney. Sandstone suitable for building purposes is also obtained at Molong, Orange, Goulburn, Burrowa, Albury, Mudgee, etc.

A very good sandstone from Kangaroo Point, in Tasmania, containing about 96 per cent. of silica, has been much used not only about in its own locality but also in Victoria. The best qualities of the stone stands the sulphate of soda test well. andstone is also obtained from North West Bay, on the Huon River, and other places in Tasmania. In Victoria good sandstone seems to be rare. There are sandstone quarries at Bacchus Marsh, from which a fair quality of stone containing about 90 per cent. of silica is obtained. Another stone, called " Darley Stone," obtained about 40 miles from Melbourne, is much used Neither Bacchus Marsh or Darley Stone can be regarded as stone of a good quality for both are unable to resist the sulphate of soda test, and experience proves that they are not durable. Sandstone of a greenish yellow colour is obtained at Barrabool Hills, near Geelong, and used largely in the adjacent districts and also to some extent in Melbourne. Another Victorian sandstone is quarried near Stawell. In Queensland sandstone is obtained at Goodna, Helidon, Murphy's Creek, Highfield, Grantham, etc.

255. SANDSTONE is a most useful stone for building purposes not only because it is fairly easy to work and if of good quality is of a durable nature, but also because it is attractive in its appearance as plain walling, and is well suited for moulded and carved work.

BRECCIA CONGLOMERATE.

256. BRECCIA and Conglomerate rocks are, like sandstones composed of pieces of older rocks held or bound together in a matrix ; but the fragments are large—that is, larger than what would be called sand—hence the difference between these rocks and sandstone. When the fragments are angular in shape the rock is called *Breccia*. On the other hand when the fragments are rounded like gravel or pebbles the formation is known as *Conglomerate*. Both Breccia and Conglomerate rocks are useful for building purposes, though, of course, not nearly so useful as the various kinds of sandstone.

257. BRECCIA occurs generally in variegated colours, and where the fragments are of Crystalline Limestone it is polished as a marble. In the Technological Museum, at Sydney, there is a sample of a fine Breccia Marble from Bathurst, N.S.W.

Conglomerate (which it may be noted is sometimes called Pudding Stone) is called quartz-conglomerate, limestone-conglomerate, etc., as the character of the rounded fragments may be.

LIMESTONE.

258. LIMESTONE is a sedimentary rock, composed chiefly of carbonate of lime, which has been formed either by chemical precipitation or from the remains of marine animals. As noted in Art. 229, extensive limestone beds have been

*Annual Report Department of Mines, N.S.W., 1894.

formed of the shells and skeletons of animals and, according to geologists, most of the limestone has been formed in this way. Shelly or erindidal limestone when of a compact character is valuable as a building stone. Many of the limestones of organic origin are, however, of a loose and crumbling nature, and quite unfitted for building work. The limestones formed by chemical precipitation are Oolite, Pisolite, Travertline, Gypsum, Dolomite, and Hydraulic Limestone. *Oolite* which is composed of very small round grains is a useful building stone. *Pisolite* is the name given to the stone when the grains are about the size of a pea *Travertine* is a concretionary formation of the carbonate of lime. Pisolite and Travertine are, like the Oolite, very valuable as building stones. *Gypsum* (hydrated sulphate of calcium) and the *Hydraulic Limestone* (*i.e.*, containing a certain amount of alumina) are used more for conversion into cements than for building stones (see Arts. 90 and 108), and need no notice under this head. The compact white and translucent variety of gypsum takes rank, however, as a rare building stone for use in ornamental work for interior decorations and is known as *Alabaster*. *Dolomite* is a Magnesium limestone composed of varying proportions of carbonate of lime and carbonate of magnesia, and is a stone of durable quality and well fitted for building purposes.

259. LIMESTONES are obtained from black to white and in colours ranging from light cream to yellow, all shades of brown, grey, bluish grey, greenish grey, and blue.

260. As a class the limestones are valuable because they are fairly easy to work, are uniform in colour over any particular kind, and if old world experience is to be taken into account, are capable of lasting a long time even in city atmospheres. The best kinds are those which are dense and of homogeneous structure and of crystalline texture

261. LIMESTONES are obtained in all the provinces, but the best known are the Waurn Ponds, Portland, and Warrnambool from Victoria and the Oamaru from New Zealand. Limestones fit for building purposes are found at Dubbo, Parkes, Orange, Cow Flat, Junee, Goulburn, Gundagai, Mudgee, Port Stephens, Bulli, Queanbeyan, Yass, etc , in New South Wales; and in Queensland at Gladstone Ravenswood, Broken River, and Rockhampton. In South Australia good limestone is obtained at Manoora, and in the Mount Gambia District.

MARBLE.

262. MARBLE is a crystalline limestone found generally in the vicinity of igneous rock, though originally formed either by precipitation or from remains of animals. Its crystalline character has been caused by the action of heat or other agents of metamorphism, and hence may be put under the heading of metamorphic rocks. The name marble is, however, by no means devoted entirely to those limestones which are thoroughly crystalline in structure, for as a general rule the name is given to all limestones which are hard enough to take a polish. For beauty of appearance marble is quite unequalled, but being comparatively scarce (i e. the more beautiful kinds) can be used only for the ornamental parts of buildings. Consequently from a constructive point of view marble has not the importance of the more abundant and generally used building stones.

263. MARBLE may be obtained either pure white or white marked with veins, black, and in all shades and arrangements of color. The most valuable on account of the rarity of its occurrence is the pure white, such as that from Carrara, which is used for statuary. This kind is composed of carbonate of lime, and has a crystalline texture like the finest loaf suguar The veins, tints, and shades which produce the beautiful *figuring* of the colored marbles are caused by the presence amongst the carbonate of lime, of minerals such as iron, etc., in an oxidised state. The black appearance of some kinds is caused by the presence of bituminous matter.

264. As pointed out above there are many kinds of colored compact limestones and breccias, which though not crystalline in structure, are capable of being polished. These stones are known as marbles. Of this kind is the encrinal or shell marble, composed of shell fossils which give the characteristic markings.

265. Very good marbles are to be obtained in various parts of the Australian continent, but up to the present they have not been much used, owing no doubt to the fact that the quarries have not been properly developed. In the Geological

Museum at Sydney there are a number of specimens of New South Wales marbles obtained from Parkes, Bathurst, Tamworth, Marulan, Orange, Mudgee and Molong. These specimens include some very valuable coloured marbles, possessing great beauty ; and the range covers from black to white, and all colors. Kapunda marble from South Australia is an attractive marble of good quality but extremely hard making it costly to work. Useful marbles are also obtained from Macclesfield and Angaston in South Australia. The Queensland marbles are obtained from Rockhampton, Ravenswood and Warwick.

266. The presence of good marble amongst our native rocks notwithstanding, it must be for a long time yet that the marbles of the older countries will be the most used in Australian architectural work. Apart from the greater beauty of the most famous of the foreign marbles, it has been the cheapest to import, for, as pointed out above, the local quarries are not properly developed, and all sorts of delays occur during the execution of the orders. It is impossible to give anything like a complete list of the most important of the foreign marbles which at the will of the architect may be imported, but the following particulars may be of value.

267. The best white marble for statuary is got from Carrara (Italy), but a creamy white of great beauty and by some preferred to Carrara is obtained from Greece ; this marble is called Parian. A white marble with dark veins called Silician from Italy is much used in all the Australian cities. Emperor's red is the name given to a very fine red marble from Portugal. Sienna, obtained from Italy is a yellow marble with veins, and is also largely imported into Australia. Rouge Royal obtained from both France and Belgium is a beautiful red and brown marble with veins. Purbeck from England, a marble much used by the mediæval builders' is a shelly marble of a grey color. Paonazza an Italian translucent white marble with dark veins is a beautiful kind for interior work.

268. The coloured marbles are used mostly for veneer work in panels, etc., for interior decorations. but they are also much used for shafts of columns, balusters, and so on. Figured marble should not be carved, for the figuring or marking renders the carving useless by destroying the lines of ornament. It is the white marbles which are specially fitted for carving, as all the gradations of light and shade caused by the curved lines and surfaces are easily apparent in the spotless material. For this reason white marble is used for statuary and for all kinds of work, such as capitals, which are enriched by carving.

SERPENTINE.

269. SERPENTINE is a massive compact rock of the metamorphic class consisting of olivine and enstatite with, occasionally, glauconite, In colour it is generally dark green, with a beautiful figured surface when polished. This rock is used in the same way as marble for interior decorations. Some very fine kinds are obtained in the provinces—a rather light green kind, with vein like figuring, from Bingera, in New South Wales, being specially beautiful.

SLATE.

270. SLATE is a rock of argillaceous composition with laminated structure. According to geologists the laminæ or planes of slaty cleavage have been caused by great pressure during the lapse of time, and though originally a sedimentary formation, may now be properly taken under the head of Metamorphic Rocks. The laminæ are not necessarily parallel to the planes or stratification—indeed, they generally make great angles therewith. Owing to the laminated or fissile structure the rock can with ease be split up into thin slabs or sheets. The better kinds of slate are much used for roof covering for which purpose the rock on account of its great hardness and resistance to water absorption is well suited. Slate is also much used for door-steps, window-cills, nosings, pavement slabs, and for various sanitary fittings.

271. SLATE may be obtained of different colours, such as red, purple, blue, green, yellow, and grey. As in the case of the other rocks, the colours are due to the presence of various metallic oxides.

272. LARGE quantities of slates are imported, the best amongst which are those from the Welsh quarries. Of the Welsh the best known are the purple and blue colours from Bangor, in Carnarvonshire. Green slates of good quality are also obtained from Westmoreland, in England. A great quantity of blue slate comes from America, but it is of very poor quality. Some green slate (also from

America) of which a lot has been used recently is of better quality than the blue coloured, but yet are not nearly so good as the Welsh kinds. Although slate of very good quality is quarried in the Australian Provinces there has so far been very little used. The Castlemaine (Victoria) grey slate is a very hard and durable kind. At Bathurst (N.S.W.) a slate of a good quality is quarried. Slate is also obtained at Mintaro, in South Australia, and at Back Creek and Piper River, in Tasmania.

273. THE foregoing Articles (221 to 272) relating to the composition and classification of the various rocks are of an abstract character, and can only be taken as indicating in a general way the properties of the building stones. It is also to be noted that the list of the localities from which the various Australian building stones are obtained are far from being as complete, as it was desired that they should be, owing to scarcity of information obtainable. It is also necessary, before passing on, to acknowledge the information obtained from the various Museums, Government Reports, Exhibition Catalogues, and the "Australian Builders and Contractors' Price Book."

274. SELECTION OF BUILDING STONES.—In the selection of stone for building purposes the matters to be considered are as follows :—

(1) Durability.
(2) Cost of getting and working.
(3) Appearance.

The matter of probable durability is, of course, the most important, though the question as to cost of getting and working cannot be disregarded ; and as a rule both of these questions have to be considered as of weight in the selection. Appearance sometimes is important, but at all times looks must be of secondary importance to lasting qualities.

275. CAUSES OF DESTRUCTION.—Before dealing with the tests for the determination of probable durability it will be necessary to notice the causes which tend to produce the decay or destruction of building stones. These causes may be set down as follows :—

(1) Rain.
(2) Wind.
(3) Variations of temperature.
(4) Vitiated atmosphere.
(5) Stresses.
(6) Wear and tear.
(7) Fire.

Rain, wind, and variation of temperature are natural causes of decay and act separately as well as conjointly to bring about destruction. The rain-water gets in to a greater or lesser degree according as the stone is porous or compact, acts on the constitutents, and changes their form, thereby producing disintegration. The wind helps by driving the rain in, and also acts separately by blowing dust and sand continually against the stone thereby wearing it away Change of temperature from hot to cold, if rapid is injurious, causing, as it does, a too sudden contraction, which is followed by cracks. A reduction of temperature to freezing point has a disastrous effect on stone saturated with water, for the increase in bulk of the water owing to freezing causes rupture throughout the saturated parts. The impure atmosphere about all cities and manufacturing towns is most injurious to many kinds of stones which contain ingredients liable to be attacked by acids. Constant wear in the building is a mode of destruction to which only some parts, such as door-steps, are subjected to. Transverse, compressive, and shearing stresses are within the control of the designer, and the stones should not be subjected to more than they can safely bear, which can be determined by experiment. Many of the building stones are quite unable to stand the temperature of ordinary fire. This is especially the case with some of the hard stones, such as granite, and there have been many serious collapses during the early stages of building fires owing to this unfortunate weakness.

276. The matter of most importance as far as durability is concerned is that the structure of the stone shall be of a favourable character. The compositions may be good but if the structure is such that the stone is loose and porous the quality of durability will be found wanting. The best structure is that of a

thoroughly crystalline character. a fact which is well illustrated by Carrara marble the composition of which is exactly the same as some of the loose and easily destroyed limestones. yet, owing to its thoroughly crystalline structure it is a most durable stone. It will be clear from what has been written above regarding destruction by rain water that smallness of percentage of water absorption is of importance for water saturation is bound to take place if the stone is loose or porous. It is, however, to be noted that hard stones are not always the most durable especially in some kinds of air, and under special conditions such as obtain during fires. As opposed to wear by abrasion or in resistance to stresses the heavier stones are as a rule the strongest.

277. EXAMINATION OF STONE.—The suitability of stone for building purposes may be determined by various methods of examinatiou and by tests. The tests and kinds of examination used are as follows :—

(1.) Microscopical examination.
(2.) Field ,,
(3.) Chemical analysis.
(4.) Acid tests.
(5.) Brard's sulphate of soda test.
(6.) Percentage of water absorption test.
(7.) Crushing, cross-breaking and shearing tests.
(8.) Fire resistance tests.

The microscopical examination is of the greatest value for under the microscope the composition. condition and combination of the ingredients and the physical structure are all exhibited so that a very reliable opinion may be formed as to the probable behaviour of the stone. Chemical analysis though useful is not nearly so good. for although the kinds and several proportions of the various constituents are determined no indication of the chemical combination is given. It is of course true that chemical analysis and microscopical examination can (at least with any degree of usefulness) only be made by those well versed in chemistry and petrology, consequently these methods are not generally within the range of the architect or builder. Experienced chemists and petrologists are however always available and their opinion should be obtained if little is known about the weathering qualities of the stone, especially if the work is important. An easy method of estimating the probable durability and one which is within the range of all to make, is what may be called a field examination. This consists of visiting the quarry from which the stone is obtained and making a careful examination of the effect of the weather upon the stone. In addition to the visit to the quarry it will be well to visit the buildings in which the stone has been used, when a further examiuation may be made as to its weathering qualities. The value of the information so gained will however, be very little if the weather and kind of atmosphere is different to that in which the stone is to be used.

278. ACID TESTS are made on stones which are to be used in an impure atmosphere. These tests are made by applying a solution of hydrochloric, sulphuric or other acid, as the case may require, and carefully observing the effects. Stones containing carbonate of lime are acted on by hydrochloric acid—the action being indicated by an effervescence which is more or less brisk as the quantity of the carbonate of lime varies

279. BRARD'S TEST is really an imitation of the action of frost, the destructive effects of which have already been mentioned. The process of testing is as follows :—A specimen of the stone is boiled for about half-an-hour in a saturated solution of sulphate of soda ; the specimen is then immersed for about a couple of hours in a cold solution of the same chemical, after which it is suspended in a dry place. The stone becomes saturated more or less, according to the degree of porosity, with the solution of sulphate of soda which crystallizes as it dries and increases in bulk with a corresponding tendency to split and disintegrate the stone. The quantity of stone detached or disintegrated is weighed, and the percentage, which it is of the original weight of the specimen carefully determined. The greater the percentage of disintegration. the poorer the quality of the stone.

280. WATER ABSORPTION.—It will be clear from what has already been written regarding destruction by rain water that smallness of percentage of water absorption is of the greatest importance, for water saturation is bound to take place if the stone is loose or porous. The percentage of water absorption may be

determined as follows:—A specimen is carefully dried and weighed; it is then immersed in water for 24 hours, after which it is again weighed. The increase of weight is then found, and the percentage which the increase is on the original weight determined. The acid, water absorption, and Brard's tests are comparatively easy to carry out, and together serve to estimate the probable lasting power of a stone in a very reliable way.

231. The Compressive, Transverse, and Shearing Tests should be made with proper testing machinery, and are only of value when made under the supervision of a competent testing Engineer. For such works as piers, columns, lintels, corbels, etc., the loads to be borne should be carefully calculated, and a sufficient quantity of stone should be allowed to provide for a fair magin of safety. Rankine has suggested that the dead load should not be more than $\frac{1}{4}$th and the live load not more than $\frac{1}{8}$th of the strength of the stone as determined by experiment.

232. Table XVIII. has been compiled to illustrate the crushing strength of the stones mostly used. As noted at the foot of the table, the specimens of granite, syenite, bluestone, and marble were not crushed by the power available during the testing by Mr. Knight. The strength of the granite and syenite would be about 8000 or 9000 lbs. to the square inch. Bluestone would stand about 15 000lbs before being crushed. The increase of weight after being six hours in water, is given for some of the specimens, but as the information is only intended to be of a comparative kind, the original weights of the specimens are not given. The specimens tested for water absorption were of the same size.

TABLE XVIII.

Showing Crushing Strength and Absorption of Building Stones Mostly Used.

	Kind.	Locality whence obtained.	Specific Gravity.	Crushing load in lbs. per sq. inch.	Amount of increase of weight after 6 hrs. in water.† oz.	dwt.	gr.	Remarks.
1	Sandstone.	Darley, Victoria.	2350	2118	2	12	0	
2	,,	Geelong, ,,	2207	2150	1	14	12	
3	,,	Kangaroo Pt., Tas.	2207	2956	1	0	0	
4	,,	N.W. Bay, ,,	2322	2089	1	7	12	
5	,,	Adelaide, S. Aust.	—	2800	1	5	0	
6	,,	Brisbane, Queensland.	—	1553		—		
7	,,	Pyrmont, N.S.W.	—	4367		—		Average of 4 tests.
8	,,	,, ,,	—	4606		—		Average of 3 tests
9	,,	Waverley, ,,	—	7731		—		Average of 9 tests.
10	,,	Parramatta, ,,	—	4110		—		
11	Trachyte.	Bowral, ,,	—	14,607		—		Average of 2 tests.
12	Limestone.	Warrnambool, Victoria.	2438	5035	0	12	12	
13	,,	Bacchus Marsh, ,,	2213	1949	2	7	12	
14	Granite.	Plenty Ranges, ,,	2655	*		—		
15	Syenite.	Gabo Island, ,,	2652	*		—		
16	Bluestone.	Melbourne, ,,	2625	*		—		
17	Marble.	Adelaide, S. Aust.	2715	*		—		

Tests 8, 9, 11, made by Prof. Warren at Sydney University. Tests 1, 2, 3, 4, 5, 12, 13, 14, 15, 16, 17 from paper by Mr. J. G. Knight, read before the Victorian Institute of Architects. Tests 6, 7, 10 from Technological Museum, Sydney.

†Specimens were of the same size.

* These specimens stood the full power of the testing machine, viz., 6720 lbs. per sq. in.

CHAPTER IX.

MASONRY.

283. SEASONING OF STONE.—Stone should be seasoned by exposure in the air some time before being set in the walls of the building. The exposure causes the quarry water, or "sap," to be evaporated, and the stone becomes harder. It is best to have the stone worked up as soon after quarrying as possible, so that the increase of hardness may take place in the finished shape of the block. It is a great mistake to rework a stone, the face of which has been seasoned by exposure, for the increased hardness seems to be greater at the face, and the removal of the "skin" makes way for rapid decay. This being the case it will be obvious that it is quite wrong to rechisel and rub down fronts of old stone buildings, as is sometimes done.

284. POSITION OF STONES.—Stones should be laid on their "natural beds," that is, they should be set with their layers of formation, or deposition, horizontal. Cornice Stones are, however, an exception to the general rule, for they should be set with the laminæ, vertical. If horizontal, the layers of the projecting parts are likely to flake off. In the case of igneous rock the position is not of importance on account of the absence of lamination.

285. BEFORE describing the kinds of stone walls it will be necessary to make clear the meaning of the following terms :—

"Scabbled" is the term given to the method of roughly finishing or dressing a stone with the axe, which is a kind of pick with chisel or axe-shaped cutting ends. "Axed" is a term given to the same kind of dressing as scabbling. "Quarry Faced" is the term for the faces of the stone left as when quarried. When the edges of the quarry face are struck off to a rough arris the face is called "pitched." A "draft" is a narrow, clean chiselled band run round near the edges of a face or bed. "Clean chiselled" means that the face is chiselled down to a smooth surface. When the surface shows a series of clearly worked furrows, left by the chisel, the work is called "Tooled."

286. STONE-WALLING may be divided into two classes as follows :—

(1) *Rubble.*
(2) *Ashlar.*

There are three kinds of rubble, namely :—

(*a*) *Common Rubble.*
(*b*) *Common Rubble built up in courses.*
(*c*) *Squared Rubble built in irregular courses.*
(*d*) *Squared Rubble in regular courses.*

287. COMMON RUBBLE consists of unhewn stones, of varying sizes, laid so as to fit between, and against, each other as well as possible, but without any attempt to arrange for courses.

288. COMMON RUBBLE BUILT UP IN COURSES is composed of the same description of stones as the Common Rubble, but, as shown at A, Figure 47, the work is levelled up to horizontal joints at regular intervals up the wall.

289. In both of the kinds above mentioned it is necessary to provide a large number of stones long enough to extend through the wall, and to have them distributed as evenly as possible throughout the wall. RANKINE says that there should be at least enough of these "headers" or "through" stones, as they are called, to have their ends make ¼th of the area of the face of wall. Such "headers" are to provide for the requisite cross bond. A great deal depends upon the mortar ; therefore it should be of good quality ; and, care should be taken to have all joints and crevices filled, to make sure of which, it is as well to have the work "grouted up" at frequent intervals. The crevices between the larger stones should be filled with small pieces of stone as well as with mortar, but, it is only in such places that the small pieces may be used, for, a wall composed of a large number of small pieces will be weak.

290. SQUARED RUBBLE BUILT UP IN IRREGULAR COURSES.—The stones for this kind of masonry are roughly squared, the beds are horizontal, and the joints are fairly uniform in thickness ; but the courses are short, and vary in height. See B, Figure 47. The remarks made above as to the quantity of headers applies

equally to this kind of rubble wall. All kinds of rubble walls should have large roughly squared or hewn corner stones, or "quoins," as shown at A and B, Figure 47, to give the necessary extra stability at the angles. The pointing of the joints of rubble work should be done with cement mortar, the degree of finish of which, of course, will depend on the importance of the work, but, it should always be done sufficiently well to keep rain water out. The usual way is to tuckpoint it with cement; the tuckpointing line being about $\frac{1}{2}''$ wide. ***Squared Rubble in Regular Courses*** or ***Coursed Rubble*** is similar to the above, but the courses are of the same thickness.

291. ASHLAR consists of carefully hewn blocks of stone, laid in courses of uniform thickness. An example of Ashlar is shown at C, Figure 47. The blocks are fairly large, but should not be very long, because, if beyond a certain length, a tendency to break, transversely, arises. The safe length is put down by authorities as not more than 5 times the depth, when good hard stone is used. In Ashlar work the courses are usually 12″ deep, so that the longest stones are seldom beyond 5′, though in first-class work where the beds are made with the utmost precision this length is sometimes exceeded. It is not, however, necessary to have all the stones of the same length, for, provided the joints are broken, the stones may vary (see C, Figure 47,) up to the maximum adopted. The breadth of the stones should not be more than 3 times the depth.

292. When the thickness of the wall is such that it is not possible to have every stone go through, it becomes necessary to provide for cross bond by having as many stones (if not right through) going as far into the wall from each face as possible. The joints of the best kind of Ashlar vary from $\frac{1}{16}''$ to $\frac{1}{8}''$, but, there is a lot of Ashlar walling done with joints much thicker.

293. The greatest of care must be taken, especially in the case of piers, to have the bed surfaces chiselled round near the edges and axed in the middle, so as to be perfectly fair and even throughout, on every stone. If one of the bed surfaces is concave and allows a bearing at the edges only, the stone will split at the joint, causing what is known as a "flushed" joint. See G, Figure 47, for an illustration of failure due to concave bed surface. On the other hand, if the bed surface happens to be convex, and consequently bearing on the centre only, the stone is likely to split in the middle as shown by H, Figure 47.

294. The outer surfaces of the stones for Ashlar work are finished in a variety of ways, the styles most generally adopted being the following :—

(1) Clean chiselled to a fair surface. (2) Clean chiselled to a fair surface, and rubbed quite smooth with stone and water. In addition to the last, the edges are sometimes elaborately moulded, and a panel worked on the face of each stone; sometimes a rabate is sunk on near its joint; this is called "*Rustic.*" (3) A margin "*draft*," either clean chiselled, or tooled, varying from 1″ upwards in width, is chiselled round the edges and the included part of the face left "*rock*" or "quarry" faced as at D, Figure 47; or finished "sparrow picked" as at E, Figure 47; or "tooled" as at B, Figure 47; or "vermiculated" as at F, Figure 47. The methods of finish are, however, multitudinous, and combinations are adopted, for instance the corner stones, or quoins, only, are often treated in an elaborate manner, and the surface of wall left with plain faced blocks. For the inside, if the wall is to be plastered, the face is roughly dressed or "scabbled."

296. On account of the thinness of the joints in Ashlar work it is necessary to have the mortar quite free from coarse grit or pebbles. The mortar used should be composed of Portland cement and clean sifted sand. The outer part of the joint, that is for about 1″ in from the face, is usually filled up with oil putty, the pointing thereof being like either one of the three sketches shown at N, figure 47, the middle one being the style which is most adopted. The vertical joints are "grouted up" and generally grooved for grouting. The grooving is formed by cutting a groove, semi-circular in cross section, in the end of each stone. The groove branches into two or three as it gets towards the bed of the stone. These grooves are cut in each stone so that they will exactly coincide when the stones are placed end to end. When the stones are set, the groove is filled with cement mortar run in as grout. The groove joint greatly increases the strength of the wall for when set quite hard the cement forms a stiff intermediate body in the form of a branch projecting into each stone and renders removal of either a matter of difficulty. A stone grooved at one end is shown at D, figure 47.

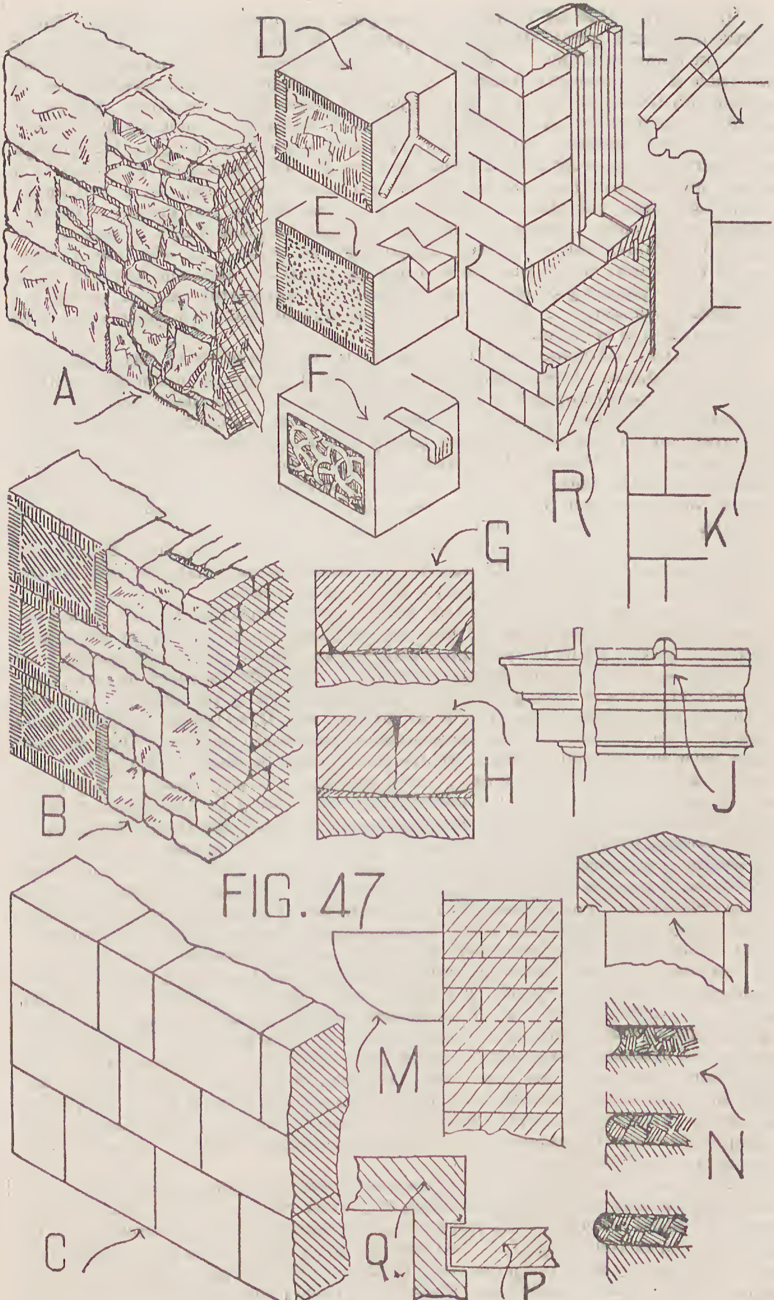

FIG. 47

297. IN THE CASES OF TOWERS and steeples, retaining walls, and other kinds of masonry where great strength is required it is usual to *dowel* and *cramp*, or *joggle* the stones together. A DOWEL is a piece of metal, or hard stone, projecting into each of two adjacent stones. A CRAMP is a piece of metal shaped so as to extend over the joint, and into two adjacent stones with the object in view of holding them together. A JOGGLE is shown at E, figure 47. Such a joggle would be made out of basalt or granite. A metal cramp is shown at F, figure 47. Cramps are generally made from 1" to 2" wide by from $\frac{1}{2}$" to $\frac{3}{4}$" thick and 12" long. Iron should never be used for cramps or dowels unless well galvanised, for it will surely oxidise and split the stone. Copper and bronze are the best metals to use for cramps. The metal cramps are bedded and held in place firmly by cement, or else by brimstone, which is melted in a pot and run in hot. It was the general custom to use lead which was run in a molten condition into the crevices, but, owing to the tendency of lead to be effected by atmospheric change, its use has been greatly curtailed. It is however still used a great deal. The joggles are held by cement run in as grout.

298. ASHLAR FACING.—In many cases it is too expensive to have the walls composed of Ashlar blocks throughout, and the facing, only, is of Ashlar, with the inner or back part composed of Rubble or Brickwork. With such work the most important matter is the question of cross bond between the facing and the backing. The cross bond is obtained by having plenty of headers from the Ashlar going well into the backing. Owing to the greater number of joints in the backing it has a tendency to settle more than the facing. Difference in settlement will cause cracks, and consequently, unstable walling. With a view to minimising the difficulty cement mortar should be used in the backing.

299. BLOCK IN COURSE.—When the courses of stones are less than 12" deep and when the work is of a rough (though not necessarily weak) character the walling instead of being called Ashlar is known as "Block in Course."

300. The vertical joint between two walls of greatly different heights should not be made by bonding the stones of one into the other, for, on account of the greater number of mortar joints in the higher wall, it will settle most, and cracks will take place as a result of the unequal settlement. The best connection is to have one wall let into a vertical groove in the other as shown by plan at P Q, Figure 47. In the sketch the wall P, is shown as let into the wall Q, so that if Q settles more than P the movement may take place without destruction to either. The vertical joints between new and old walls should, also, always be made in this way.

301. STONE FOOTINGS.—It was pointed out in Art. 72 *ante* that Masonry is not as good as concrete for footings; neverthless it often happens that masonry if not altogether unavoidable is owing to circumstances of supply the most convenient to use. Footings for very light walls may be composed of rubble masonry, but where the weight is at all considerable the stone should be in large blocks. The stones should also if possible be wide enough to allow of the bottom course being in single stones crosswise. In some cases where the walls are of great weight it is impossible to have only one stone in the width of each course of the footings. More than one stone in the width necessitates careful bonding, and also that the courses shall be well bedded. For such work the stones should at least be roughly squared, but, if possible, the bed joints should be prepared with chisel draft and axed to a fair surface. The best kinds of stone to use for footings are granite, syenite, basalt, and the best of hard sandstone. BASE COURSE.—A course of stone generally about four or five courses of brickwork deep, is very often built in at about the level of the ground floor, in external brick walls, to mark the difference between the basement and upper walls, see Fig. 35, which shows a base course a little thicker than the super-imposed brick wall, with the upper edge of the face moulded. The example illustrates the general rule but the upper edge of the face is more often splayed or weathered than moulded.

302. STONE CORNICES and string courses should be composed of long stones with their laminæ vertical and laid with very close vertical joints. In the best work it is usual to form a little ridge along each joint on the weathered top of the cornice. See sketch J, fig 47. This method of top finish causes the water to be turned off quickly from the joint, thereby preventing the water soakage and consequent decay which takes place when the cornice joints are wide and carelessly made. The ridge is small being only about 1" high and 2" wide. The exposed

plane and curved surfaces of the cornices and string courses are finished either, clean chiselled only. or clean chiselled and rubbed smooth. Care should always be taken to so proportion the projection of the cornice that its weight will be fully counterbalanced by the superwalling or blocking course. In the case of crowning or pediment cornices having no blocking course or superwalling above, the overhanging part should be much lighter than the part resting on the wall. When the cornice is to be put on the side as well as front walls care must be taken with the corner cornice stone. The cornice stones along the straight of the walls have projection from one side only, but the corner stone will have the projection from two sides. consequently in a case where the cornice along the wall is just counterbalanced the corner piece would be overweighted if not given extra superwall. The extra superweight is generally put in the form of some kind of corner ornament such as a pedestal with urn or statue.

303. In case of cement stucco cornices or string courses, the inside or "core" of the projection is generally composed of stone roughly hewn to a shape somewhat smaller, but approximating to that of the finished cornice. The "cores" are set in the wall and the cement mouldings run on them.

304. STONE COPINGS should be built with stones as long as possible, for the fewer joints the better. In good work it is best to have the joints ridged at the top, as described for cornices in the last article. Sometimes the tops of the copings are rounded, sometimes sloped to one side only, and at other times sloped or weathered to both sides, as at 1, Fig. 47. In no case should the coping be quite flat on the top. The coping should project on each side so as to effectually protect the wall. The projection is seldom less than 2", but may range from 1" upwards at the will of the designer. In all cases the lower surface of the projection should have a groove called a "throat" run along it as shown at 1, Fig. 47. When inclined as on a gable the coping should be secured at the lowest point by a stone called a "kneeler" (see L, Fig. 47), which is built into the wall and makes a solid footing.

305. DOOR STEPS should be in single stones and the quality should be of the hardest. Granite and Basalt make excellent door steps. Slate, in slabs about 2" thick, is also a good stone for the purpose and it is much used. In ordinary house building the kind most used is sandstone, but it is not able to stand the constant attrition and wears away very quickly. Door steps are generally clean chiselled on exposed surfaces, and in the case of sandstone the surfaces are occasionally rubbed fine. A more elaborate finish, such as nosing and mouldings, is often put on. The stone for door steps should be at least 9" longer than the width of opening, so that there may be 4½" into the wall on each side. The ends of the steps, only, should be bedded, that is to say, the middle parts should not rest on the wall underneath. This is to prevent breaking, which is likely to occur should the parts of the wall on each side settle more than that under the door opening. If built in brickwork the thickness of the stone steps should be such as to correspond with some number of courses of brickwork. *Approach Steps*, like the door steps, should always be of hard stone.

306. WINDOW SILLS.—The form of plain window sills generally used is shown at R, Fig. 47. This kind runs either 4½" or 9" into the wall on each side of the opening and projects about 2" from the face of the wall, the under surface of the projection always being "throated" as shown. The top from the wood sill is "weathered" with a good slope downwards towards the front, while the projections of the ends are finished on top with a scotia or splay. To make sure of keeping the water out it is best to put a water bar of galvanised iron or copper into the top of the sill and into the bottom of the wood sill as shown by the sketch. As in the case of the door steps the sills should be bedded only at the ends. If the sills are to be used in brickwalling the thickness should correspond with some number of the courses.

307. A LINTEL is a stone beam spanning an opening and carrying the superimposed wall. When the span is beyond three or four feet it is necessary to have a relieving or discharging arch built over the lintel. The arch is of stone or brickwork, as the wall above may happen to be, and is built on the same principle as the relieving arch, illustrated at B or C over the wooden lintel A, Fig. 42. If the walling be brickwork the bearings of the lintel on each side of the opening should be either 4½", 9", or 13½", so as to suit the bond of the brickwork ; while the height

should agree with some number of the courses. Thin column-like vertical pieces of stone called "Mullions" are often used to divide a large lintel headed opening. In such cases care must be taken to avoid building the ends of the lintel into heavy pieces of walling, for the settlement of the piers and mullions will be unequal, and either the lintel will be broken or the mullions crushed. Good hard stone should be used for lintels, and if of a laminated structure the layers should be vertical with their direction in the length of the lintel. A composite lintel is formed with three stones across the span; the centre stone being put in like a keystone in an arch.

308. A CORBEL is a stone, or stones, projecting in the form of a bracket to support a weight such as a girder in the spring of an arch. A plain corbel is shown at M, Fig. 47. Corbels permit of treatment as architectural features, and oftener than not are moulded and carved in an elaborate manner. Constructively they should be strong enough to prevent being broken off by the weight upon them, and care should be taken that the top bearing surface is perfectly level, for, if the weight acts at the outer top corner or edge breakage is more liable to occur.

309. BUTTRESSES are projecting masses of masony built at intervals along a wall to increase its strength. They are usually diminished in projection as the upper part of the wall is reached, and the parts at which the decrease in projection is made are sloped off, generally as shown at K, fig. 47. To effectually serve their purpose the buttresses should be well bonded to the walls and should have good foundations.

310. MASONRY ARCHES are built on the same principles, and the terms used in connection with them are much the same, as described in the articles 203, 206, 207, 208 and 209 *ante* on brick arches, the main difference being that the arch stones or voussoirs are all (unless in the very roughest rubble work) cut to the particular taper required. The outer edges or "drafts" of the joints should be very carefully clean chiselled and the inner parts of the joint surfaces carefully axed, for, as the arch stones have to do relatively more important work than the stones in the walling, failure from "flushed" joint, or round joint surfaces, should be specially guarded against. All the joints should be grooved for grouting as described in Art. 296 *ante*.

311. TRACERY.—The stone used for the window decoration peculiar to Gothic architecture must be of a kind, such as sandstone, which can be easily worked, on account of the great amount of cutting and dressing necessary to produce the slender and gracefully curved moulded bars which form the *tracery*, as it is called. The various pieces to form the tracery should be very carefully jointed so as to avoid unsightly "kinks," or bulges, and should be dowelled together with copper or stone dowels. The "cusps" or triangular projections from the inner courses of the tracery should not make lesser angles than 60°, for, if less, the stone at these points will be too thin and will be rapidly decayed away.

312. STONE COLUMNS up to about 15′ in height are made with the shaft out of one piece of stone, but, when exceeding this height, they are usually built with the shaft in several pieces. There are, of course, cases where very tall columns have been made with the shafts as monoliths, but the great expense incurred is sufficient to prevent such being the general rule. The caps and bases are, in all but very small columns, made in separate pieces. Where the columns are to bear weight it is of the greatest importance to have all the joints of bases and caps and joints of shafts (if the shafts be in several pieces) made perfectly true and at right angles to the axes of the columns. In addition to perfect joints, it is also necessary to have the columns set with their axes vertical. Another matter to be attended to is the bearing of the lintel, or other part of the superstructure, on the caps, for, care should be taken that the weight does not come on the *abacus*, or carving, but is borne by the solid part, which should be carried up about ½″ to above the *abacus*.

313. TEMPLATE (or templet) STONES are placed in a wall, or on a pier, under a girder or other beam to distribute the weight. They should always be of a hard strong stone, and the thickness in all cases should be at least one third of the narrowest dimension. A piece of lead, or leather, should be interposed between the under surface of the girder and the upper surface of the template to mitigate the evil effects of irregularities which may be left after the dressing of the stone surface.

314. Protection of Stone Dressings.—All the various parts of the stonework, such as doorsteps, window sills, mouldings and other ornamental work, should be cased in with timber, as soon after being set in position as possible, so as to prevent damage from falling material, and from the operation of the workmen. Care should, however, be taken that the timber used for the purpose will not stain the stone, as will, for instance, most of the Australian hardwoods.

CHAPTER X.

BUILDING TIMBERS.

315. Putting on one side the relative values of different timbers (these will be dealt with hereafter) and taking the matter of felling in a general sense, the most important points to be attended to are the suitable age of the tree and the best season for felling it.

316. The best age to fell a tree is when it has reached maturity, that is to say, when it has got to the age after which its growth ceases to improve it, for, although a tree does continue to grow after having arrived at maturity, the rate of growth is very slow, and is attended with decay, especially in the heartwood. On the other hand, if cut down too young there will be a large proportion of sapwood, and the heartwood will be wanting in hardness and density. Considerable experience is needed to judge with accuracy as to the time when maturity is just reached, but it is not difficult to distinguish when that condition has been passed, for the defects, such as heart decay, which inevitably occur, and the great decrease in the rate of growth, are good indications.

317. BEST SEASON TO FELL TREES.—Trees should be felled when the sap is not circulating, otherwise the timber got from them will be largely impregnated with sap, and will be sure to decay quickly. In tropical climates the sap is at rest in the dry season, while in temperate and cold places the winter is the time when the sap is down. It is difficult to lay down any hard and fast rule for guidance in this matter on acount of the overlapping of the climates, and the peculiarities of various districts. It is, however, a very safe rule to avoid cutting down a tree if it is sending out new shoots and leaves.

318. SEASONING TIMBER.—Although every effort should be made to fell trees only at the time that they contain the least sap, it is impossible to find a time when a living tree will contain no juice or sap. Whatever there is of sap must be got rid of, for, if left in the timber it becomes an active element of destruction instead of as originally a means of nourishment, and a necessity of life. Moreover if made into Carpentry or Joinery work while in a "green" or jucy condition much trouble will be caused by its twisting and cracking. The expulsion of these juices is called *seasoning* and is brought about by either natural or artificial means.

319. Natural seasoning is carried on by exposing the timber in stacks so that the air may get all round it but, it should be protected from the Sun's rays, and from strong winds. The air dries the sap out, but, the process is very slow, for it takes about four years of such exposure to fit a timber for Joinery work. The Australian hardwoods behave very badly under the process of natural seasoning for, the explusion of the sap by such means causes such large and numerous cracks, and so much twisting and warping, as to render a large percentage useless. It seems, therefore, that in the case of hardwoods at least, a system of artificial seasoning whereby the juices may be removed without cracking the timber is greatly needed. For the sake however, of expedition and thoroughness, there is much to be said in favour of artificial seasoning for all the timbers.

320. ARTIFICIAL SEASONING consists of extracting, by some means, the sap more quickly and perhaps, more thoroughly, than can be done by natural seasoning. There are many methods of artificially seasoning timber and many have been tried with success though not extensively, in Australia. Several of the methods are as follows :—

(1) The timber is put into chambers and thoroughly steamed. Hot air is then injected into the chamber and the timber is well dried.

The following table * shows the results of the treatment by this method of some specimens of Australian Hardwoods ; judging from the great decrease in weight a large amount if not all of the sap must have been removed.

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*From Proceedings of the Royal Society, N.S.W.

Kind.	Green.		Seasoned.	
	Weight in lbs.	Size in inches.	Weight in lbs.	Size in inches.
Blackwood ...	110	$12\frac{1}{6}$ x 2	52	$11\frac{1}{2}$ x $1\frac{15}{16}$
Blue Gum ...	113	$10\frac{1}{4}$ x $2\frac{1}{8}$	84	$9\frac{7}{8}$ x $1\frac{7}{8}$
Stringy Bark ...	108	$10\frac{1}{4}$ x $2\frac{1}{8}$	82	$9\frac{7}{8}$ x $1\frac{7}{8}$

(2) Drying in hot air chambers without first steaming is often adopted; the air being heated to about 130°. The process is not as good as that above described, for the rapid action of the hot air is liable to crack the wood.

(3) Another method (described in "Rivington's Notes on Building Construction") which is called McNeile's method, consists of treating the timber in chambers filled with moist air charged with certain gases evolved from the combustion of fuel under the chamber.

This process which is a patent one is largely used in England, and it is claimed that the wood treated by it is rendered harder and tougher, and, impervious to dry rot.

(4) Water seasoning consists of putting the timber under water for some time, until the sap is driven out after which the timber is dried in the air. Salt water is the best for the immersion, as it makes the timber harder and more durable, but has the drawback that it imparts to the timber the power of permanently attracting moisture. The timber should be fully submerged for half under, and half out of the water, will do more harm than good.

321. Before passing on it is necessary to mention that some authorities on the subject contend that artificially seasoned timber is not so strong as that which has been naturally seasoned. If this is so, it is a matter still, for debate as to whether the artificially seasoned is not even then the best on account of the improved chances of durability.

322. Selection of Good Timber.—The best part of the trunk of the tree is the heartwood, for, the outer part under the bark called the sapwood is the newest wood and is loose and spongy. The timber should therefore be from the heart of the tree. It should be free from sap or in other words thoroughly seasoned, and defects such as sun cracks, heart shakes (i.e. cracks radiating from the centre of the tree), cup shakes (i.e. circular cracks dividing the concentric layers of the wood) and gum veins. Knots should be avoided unless the timber is selected for appearance in which case the sound knots are often the centres of beautiful figures or markings.

323. Causes of the Decay and Destruction of Timber.—The causes of decay and destruction of building timbers may be set down as follows:—

(1) Fermentation of sap, causing decomposition of the wood.
(2) Permanent dampness causing the development of wet rot.
(3) Want of ventilation causing the development of dry rot.
(4) Alternate conditions of wet and dry.
(5) White ants.
(6) Teredo.
(7) Fire.

324. The First Four Causes can with care and intelligence be easily avoided, for, it the timber is well seasoned there can be no trouble from fermentation of the sap, while permanent dampness, or want of ventilation, can in house building exist only where there has been bad design or carelessness. The wet rot is a decomposition under conditions of excessive and continuous moisture, while the dry rot follows upon exposure in close confined and ill-ventilated places. The latter is a disease in the form of a fungus which eats into the fibres of the timber and reduces them to the condition of a dry powdery dust.

325. White Ants. These insects abound in all parts of Australia, and destroy enormous quantities of timber annually. It is not at all uncommon to find cases where parts of buildings such as floors, roofs, and fittings are eaten away and

rendered unsafe by these insects. They are very small, being not more than ¼in. long, and a nest comprises millions of them. They eat away the wood from the inside without giving any outward indication of their presence. It is not certain that any kind of timber is exempt from their attack, though they go for the native timbers in preference to the imported kinds. There are many preparations in the market for coating timber to render it proof against them; but, if these washes are to be effective, care must be taken that the ants are not in the timber when supplied from the mill, for the solution may not penetrate right into the timber and their destructive action would be unchecked. The refuse from kerosene refineries called kerosene tar is good as a coating to guard against them, and is rendered even more effective if arsenic is dissolved in it. When excavating the ground for the footings, etc., a search should be made for old stumps and such should be carefully removed as oftener than not white ants are contained in them.

326. **The Teredo** is a marine worm which does much damage to timber submerged in or near salt water.

CLASSIFICATION AND DESCRIPTION OF THE PRINCIPAL BUILDING TIMBERS USED IN AUSTRALIA.

327. **The Indigenous Timbers** of Australia are of excellent quality, and plentiful, and they are freely used in all kinds of building work, but, exotic timbers are also imported in large quantities and extensively used. A description of the building timbers, to be of use to the builder, must, therefore include the imported as well as the native kinds.

For the sake, however, of clearness the imported timbers are taken separately.

328. The following is a convenient practical Classification of the various timbers :—

1. *Australian Hardwoods.*
2. *Australian Soft Woods and Figured Timbers.*
3. *Imported Hardwoods, Soft Woods and Figured Timbers.*
4. *Australian Pinewoods.*
5. *Imported.* ,,

329. **The Australian Hardwoods** are of the genera Eucalyptus, Syncarpia, Angophora, etc. The timber is of a close texture, heavy, and very hard. Most of it is, however, subject to cylindrical splits, which are filled with gum, and when drying or seasoning these splits or cupshakes are also developed. These defects arise from what may be called a remarkable feature of the trees of the Eucalyptus genus, namely, a tendency to split in concentric layers, rather than in planes radiating from the pith or centre of the heart. The principal kinds are classified as follows :—

(1) *Ironbark of various kinds.*

(2) *Pale hardwoods.*

- (a) Blackbutt.
- (b) White Mahogany.
- (c) Tallow Wood.
- (d) Spotted Gum.
- (e) Grey Box.
- (f) Stringybarks.
- (g) Peppermints.
- (h) Brush Box.

(3) *Red Hardwoods.*

- (a) Red Mahogany.
- (b) Grey Gum.
- (c) Murray Red Gum.
- (d) Forest Red Gum.
- (e) Sydney Blue Gum.
- (f) Wollybutt.
- (g) Bloodwood.
- (h) Jarrah.
- (i) Karri.
- (j) Turpentine.

In the description which follows the genera and species, as well as vernacular names are given.

330. IRONBARK.—There are five kinds of Ironbark, namely :—

1. White or Grey Ironbark.	*Eucalyptus.*		*Paniculata.*
2. Narrow-leaved	,,	,,	*Crebra.*
3. Broad ,,	,,	,,	*Siderophloia.*
4. Red	,,	,,	*Sideroxylon.*
5. Silver ,,	,,	,,	*Melanophloia.*

331. WHITE IRONBARK is the best of the five kinds, being the hardest and stongest. Obtained from Queensland, N.S.W., and Victoria.

332. NARROW-LEAFED and BROAD-LEAFED IRONBARKS are of a red colour, and are valuable timbers though not so good as the White or Grey Ironbarks. The narrow-leaved species is found in the costal districts of Queensland, and in N.S.W. as far South as Port Jackson; while the Broad-leaved Ironbark belongs to Southern Queensland, and N.S.W. from Port Jackson northwards.

333. RED IRONBARK is deep red in colour. It is a good timber, though inferior to the three kinds before mentioned. It grows in Southern Queensland, N.S.W., Victoria, and South Australia.

334. SILVER-LEAVED IRONBARK is not valuable, the trees being small and stunted.

335. Taking the Ironbarks generally, they are unquestionably the best of the Australian Hardwoods, being unequalled for strength in combination with durability. The timber may be distinguished by the texture, which much resembles that of horn, and a "gumminess" which is noticeable when planing it. It is difficult to work up to a smooth surface, for, unless a very sharp tool is used it tears very much. Ironbark is principally used in building work for storey posts and beams, but it serves well for any work where hardwood may be used.

2.—PALE HARDWOODS.

336. (a) BLACKBUTT. *Eucalyptus Pilularis*—This is a strong durable timber of a yellowish brown colour. It is generally straight grained, though at times it is found with a grain closely interlocked. Blackbutt grows in Victoria, New South Wales, and Southern Queensland. It is used for all kinds of house carpentry work.

337 (b) WHITE MAHOGANY. *Eucalyptus Acmenoides.*—This timber is of a whitish yellow colour, straight grained, and is noted as being durable. Chiefly used for flooring boards, slabs, rails, and palings. It grows in South Australia, New South Wales, and Southern Queensland.

338. (c TALLOW WOOD *Eucalyptus Microcorys*—A timber of excellent quality; pale to dark yellow in colour, greasy in its nature, strong, durable, and easily worked. It is not so liable to shrink as the other hardwoods, whilst its distinguishing feature is its greasy nature above referred to. It is an excellent timber for storey posts, beams, joists, flooring boards, door and window frames, sills, weatherboards, turnery, posts, rails, and indeed for building purposes generally. Though Tallow Wood is different to Blackbutt and White Mahogany, these latter timbers are often supplied where Tallow Wood has been wanted, for, the three timbers are somewhat alike as regards general appearance. This substitution should be guarded against, for, although Blackbutt and White Mahogany are good timbers they are not equal to Tallow Wood. Tallow Wood grows in northern coast disricts of New South Wales and up to Cleveland Bay in Queensland.

339. (d) SPOTTED GUM. *Eucalyptus Maculata.*—This timber is used extensively in building work. It is of a light yellow brown colour, with a close wavy grain, very durable, and is tough, being particularly suitable for bending. *Eucalyptus Maculata* grows in New South Wales and up to centre of Queensland. It does not grow in Victoria; the spotted gum of that colony being a species (viz., *Eucalyptus Goniocalyx*) inferior in quality.

340. (e) WHITE OR GREY BOX. *Eucalyptus Hemiphloia.*—Of a whitish yellow colour, very heavy, hard, tough, and close grained. It is not easily worked, but is suitable for posts, joists, rails, and other such work. Grey Box grows in New South Wales, Victoria, South Australia, and Southern Queensland. A report was submitted, in 1896, to the Minister for Mines and Agriculture, N.S.W., by a

Committee appointed to inquire as to its value. The report, which has been published, contains means of information of a very valuable chaaacter, and, as a whole favourable to the timber.

341. (f) STRINGY BARKS. *Eucalyptus Capitellata*, *Eucalyptus Macorrhyncha*, *Eucalyptus Eugenioides and Eucalyptus Obliqua.*—*E. Capitellata* is a straight grained, tough. durable dark yellow brown timber. It is generally called brown stringybark. It grows in Queensland, Eastern Victoria, and New South Wales. *E. Macorrhyncha* is a stringy bark of New South Wales and Victoria. It is dark yellow and straight grained. *E Eugenioides*, called "stringybark," "white stringybark," and "Broad-leaved stringybark," is a pale coloured fissile timber which grows in Victoria, New South Wales, and Southern Queensland. *E. Obliqua* is a very fissile timber. light to dark brown in colour, which is very much used for shingle posts, rails, palings etc. It grows in South Australia, Victoria, Tasmania, and Southern New South Wales.

342. (g) PEPPERMINT *Eucalyptus Piperita and Eucalyptus Amygdalina.*—The former (*E. Piperita* is a durable timber which grows in Victoria, New South Wales, and Queensland. *E. Amygdalina* grows in Victoria, Tasmania, New South Wales. and it is a durable, straight grained, and comparatively light timber. Both of these species are used as a rule only for posts and rails. shingles, and such rough carpentry work.

343.—STRINGY BARKS are often called peppermints. and *vice versa*, while peppermints are at times called *Messmate*. The timbers of these species are inferior to the other pale hardwoods mentioned in the preceding articles. and should not be used for other than rough building purposes.

344 (h) BRUSH BOX. *Tristania Conferta*. This timber possesses toughness, strength and durability. It is of a grey brown colour and has an interlocked grain. Unless carefully seasoned it splits and warps very badly. Brush Box grows in Northern Australia, Queensland and New South Wales.

3. RED HARDWOODS.

345 (a) RED MAHOGANY. *Eucalyptus Resinifera*. An excellent timber of a rich red colour strong and durable; which becomes very hard with age. It resembles the American Mahogany but is of a different order. This timber is suitable for building purposes generally, but is mostly used for weatherboards. Red Mahogany grows in New South Wales and Queensland. This timber has the reputation of resisting the Cobra.

346 (b) GREY GUM. *Eucalyptus Propinqua*. A valuable red-coloured, close grained, hard timber, which is very durable, and much resembles though is not as strong as ironbark. for which it is often substituted. It grows in New South Wales and Queensland, and is used for all kinds of building work but principally for posts. beams, joists rafters and shingles, frames and fencing.

347 (c) MURRAY RED GUM. *Eucalyptus Rostrata*. A timber of a dark red colour very hard, and consequently difficult to work, but very durable under the worst conditions, and is not destroyed by the teredo or by white ants. It can be used in building work to a great extent, but not. generally, in places where it would require to be worked up with smooth surfaces. It grows over the whole of Eastern Australia.

348 (d) FORREST RED GUM. *Eucalyptus tereticornis*. This timber is closely related to the Murray Red Gum described in the preceding article. It is a heavy close grained, light to dark red coloured timber which grows in Victoria, New South Wales and Queensland. It is useful for posts, beams, joists, rafters frames, flooring and fencing.

349. (e) SYDNEY BLUE GUM. *Eucalyptus Saligna*. A red coloured close wavy grained timber, which may be easily worked. This timber is suitable for posts, beams, joists, rafters frames, sills. weatherboards flooring, and such, parts of building work. It grows in New South Wales and Southern Queensland.

350 (f) WOLLYBUTT. *Eucalyptus longifolia*. A timber which is defective on account of gum veins, and as a consequence is not much used in building work. It can, however, be sometimes obtained in a sound condition, when it may

be used for such purposes as posts, joists, rafters and rails. It grows in Southern New South Wales and Victoria.

351 (g) BLOODWOOD. *Eucalyptus Corymbosa.* Like the Woollybutt this timber is subject to ugly gum veins so that it is not of much value for building work. It is generally used for posts and rails. It is durable; and it is claimed that it can resist the white ants; while it has, excepting for the gum veins, a pleasing appearance when planed up to a smooth surface. It grows in Southern Queensland and Eastern New South Wales.

352 (h) JARRAH. *Eucalyptus Marginata.* This is a remarkably fine West Australian hardwood, which, of late years, has attracted much attention. It is of a red colour (much like Red Mahogany in appearance) with a close texture and slightly wavy grain. It is easily worked to a smooth surface. Jarrah, though not as strong as some of the other Eucalypti possesses the quality of durability in a high degree and is able to withstand the *teredo* and white ants. It is suitable for posts, beams, joists, rafters, framing, weatherboards shingles, flooring, turnery, etc.

353. (i) KARRI. *Eucalyptus Diversicolor.* This is a light red coloured heavy fairly straight grained tough timber. It does not work up easily, but is a useful timber for posts, beams, joists, rafters, and such parts of buildings. It grows in South Western Australia.

354 (j) TURPENTINE. *Syncarpia Laurifolia.* This is a dark red brown colored timber, which is difficult to burn, is capable of resisting the teredo and white ant, and is durable under the worst conditions of damp. It is however liable to warp and twist very badly if not well seasoned. It is especially valuable for piles, but may be used if well seasoned for storey posts, beams, joists, rafters, frames, and such other parts of buildings. It is very slow to burn, which should be a recommendation for it as regards buildings. It grows in New South Wales and Queensland.

AUSTRALIAN SOFT AND FIGURED TIMBERS.

355. The following are the most important of the soft and figured timbers of Australia :—

(a) Cedar.	(h) Black Bean.	(o) Corkwood.
(b) Rosewood.	(i) She Oak.	(p) Coachwood.
(c) Red Bean.	(j) Silky Oak.	(q) Muskwood.
(d) Onionwood.	(k) Red Silky Oak.	(r) Tulipwood.
(e) Colonial Beech.	(l) Honeysuckle.	(s) Maiden's Blush.
(f) Blackwood.	(m) Flindosa.	(t) Blueberry Ash.
(g) Myall.	(n) Native Teak.	(u) Red Ash.

356 (a) CEDAR. *Cedrela Australis.*—This is a soft, but durable, red coloured timber, beautifully figured, which much resembles Mahogany, and has to an eminent degree all the qualities to fit it for use in the best kinds of joinery and cabinet work. It grows in New South Wales and Queensland, but owing to indiscriminate use, and large waste in the past, it is not very plentiful. It is generally used in first-class work for jambs and doors, window frames and sashes, architraves, skirting, staircases, show cases, counters and other such internal fittings. It is the very best timber for the plugs used in joinery work to afford nail hold in the walls.

357 (b) ROSEWOOD. *Dysoxylon Fraserianum.*—A medium soft, red coloured timber, which, like the Cedar, also resembles Mahogany. It is of excellent quality, and being plentiful can be cheaply obtained. It can be used for all kinds of joinery and cabinet work and is a good substitute for Cedar. It grows in Queensland and Northern New South Wales.

358 (c) RED BEAN. *Dysoxylon Muelleri.*—This is another red coloured timber which is valuable for joinery work. It is very like Rosewood in appearance and quality. It grows, but not plentifully, in Northern New South Wales and Queensland.

359 (d) ONIONWOOD. *Owenia Cepidora.*—This timber is like Cedar as far as texture is concerned but is of a different colour, being a light yellowish red. It is useful for all kinds of joinery work.

360 (e). COLONIAL BEECH. *Gmelina Leichhardtii.*—This is a very light yellow coloured, soft but close grained, and exceedingly durable timber which

does not warp. It is principally used for flooring, but it is of sufficient value to admit of its use in all kinds of joinery work, although it is plain in appearance. Colonial Beech grows in Queensland and New South Wales.

361 (f). BLACKWOOD *Acacia Melanoxylon*.—This timber is exceedingly valuable for the best kinds of house fittings and cabinet work. It is very hard and has a dense texture with a very pretty figure, and resembles American walnut. Unless very carefully seasoned it warps rather badly. The best comes from Tasmania, but it also grows in South Australia, Victoria and New South Wales.

362. (g) MYALL. *Acacia pendula* and BRIGALOW *Acacia harpophylla* are hard, heavy, dark coloured timbers which are principally used for turnery work. They are obtained from New South Wales and Queensland.

363 (h.) BLACK BEAN. *Castanospermum Australe*.—A figured brown coloured timber which is fairly hard, and somewhat like Blackwood in general appearance. This timber is principally used for cabinet work, but, could be used for many kinds of joinery work. It grows in Northern New South Wales and Queensland.

364 (i.) SHE OAK, FOREST OAK, SWAMP OAK. *Casuarina of various species*. These timbers are hard and durable. and. though like the oaks described in the following articles not of the same genus as the English Oak, they are much like that famous timber in grain. They are generally of a red colour. These oaks make splendid shingles.

365 (j.) SILKY OAK. *Grevillea Robusta*.—A hard, buff coloured timber very like English Oak, though not of the same genus It is elastic, strong and durable and well fitted for joinery work. Silky Oak grows in New South Wales and Queensland

366 (k) RED SILKY OAK sometimes called BEEFWOOD *Stenocarpus Salignus*.—This is a red coloured timber with a peculiar uniformly undulating figure. It is a hard timber, but not difficult to work, and is suitable for cabinet work and for panels, etc., in joinery work. Red Silky Oak grows in New South Wales and Queensland.

367 (l) HONEYSUCKLE. *Banksia Serrata*.—A handsome timber of a red colour with a grain somewhat like English Beech. It is hard and fairly durable, but requires to be very carefully seasoned. Honeysuckle grows in Tasmania, Victoria, New South Wales and Queensland.

368 (m) FLINDOSA. *Flindersia Australis*, and (n) NATIVE TEAK. *Flindersia*—Flindosa is a very hard close-grained timber of great strength. It is of a pale colour and resembles Colonial Beech for which it is often substituted. Flindosa (or Cudgerie as it is sometimes called) is generally useful in building work. Native Teak is a hard heavy timber which is difficult to work but very durable. These timbers grow in New South Wales and Queensland.

369 (o) CORKWOOD *Ackama Muelleri* (p) COACHWOOD. *Ceratopetalum Apetalum*.—These timbers are of a light colour, exceedingly tough, and very suitable for joinery work. They grow in New South Wales.

370 (q) MUSKWOOD. *Olearia Argophylla*.—This timber takes its name from its pleasing fragrance. It has a pretty, mottled appearance and is suitable for panels and such work Obtained from New South Wales, Victoria and Tasmania.

371 (r) TULIPWOOD. *Harpullia Pendula*.—A close-grained pretty timber, in shades from yellow to black. It is suitable for panels. Grows in New South Wales and Queensland.

372 (s) MAIDEN'S BLUSH. *Echinocarpus Australes*.—A timber of a light yellowish brown colour very soft but durable and chiefly used for ornamental purposes. Grows in New South Wales and Queensland.

373 (t) BLUEBERRY ASH. *Elaeocarpus Cyaneus*.—This is a dark coloured, tough timber which in quality resembles English Ash. It grows in New South Wales, Victoria, Queensland and Tasmania.

374 (u) RED ASH. *Alphitonia excelsa*.—This timber is sometimes called Mountain Ash. It is close-grained, hard and durable, and is tough. It is suitable for building purposes generally. Red Ash grows in New South Wales, and Queensland.

IMPORTED HARDWOODS AND FIGURED TIMBERS.

375. The most important of these timbers are as follows :—

(1) Oak.
(2) Mahogany.
(3) Ash
(4) Elm.
(5) Teak.
(6) Beech.
(7) Walnut.
(8) Rosewood.
(9) Maple.

There are other timbers such as Hickory, Box, Lignum Vitæ, Willow Yew, etc., which are imported in small quantities for special purposes, but, not in connection with building; hence they are not dealt with here.

English and foreign hardwoods and figured timbers are not regularly kept by Colonial timber merchants as the cost of landing them precludes their use in other than first class buildings, and then only in the best of the joinery and cabinet work They may, however, be imported as occasion demands.

376. (1) OAK. This timber grows in various parts of Europe and America. The kinds known to commerce are as fo'lows :—

(a) English Oak.
(b) Bay Oak.
(c) Durmast Oak.
(d) American Oak.

377. (a) ENGLISH OAK *Quercus Pedunculata.* This is the best kind of oak, being exceedingly strong and durable, with a straight and fine grain; its colour being brownish yellow.

378. (b) BAY OAK. *Quercus Sessiliflora.* A timber almost of the same quality as English oak, but it is less dense and is liable to warp.

379. DURMAST OAK. *Quercus Pubescens.* This kind is not so good as the two mentioned above.

380. AMERICAN OAK. *Quercus Alba.* This oak, though not so good as the English kinds, is a tough, durable timber of a whitish brown colour with a reddish tinge, the grain being coarse and straight.

381. OAK is noted as being a very durable timber of great strength and possessing a pleasing appearance. However, as before noted, it is only possible to use it here for internal fittings, for which it is very suitable. The timber is sold in the English market in logs from 10 to 16 inches square, and from 18 to 30 feet long, and in planks from 2 to 8 inches thick, from 9 to 13 inches wide, and from 24 to 35 feet long. The American oak is sold in logs from 12 to 24 inches in thickness by from 25 to 40 feet long

382. MAHOGANY. *Swietenia Mahogani.* This well known timber grows in America and the West Indies. That known as "Honduras Mahogony" grows in the country surrounding the Bay of Honduras, and also in Brazil; while that called "Spanish" Mahogany grows in Cuba and other islands of the West Indies. Honduras mahogany is straight grained, as a rule, and is of a red brown colour. It is sold in the English market in logs 2 to 4 feet square by from 12 to 14 feet long. Spanish mahogony is the best as far as appearance is concerned for it has a beautiful wavy grain. Spanish mahogany is sold in the English market in logs 11 to 24 inches square by from 18 to 35 feet long. This timber is used occasionally for internal fittings but Australian people know it mostly as a furniture timber.

383. ASH. *Fraxinus Excelsior.* A durable. tough, and very elastic timber, easily worked, and of a brownish white colour. It is used in small quantities in good joinery work. Ash grows in Europe Asia and America.

384. ELM. *Ulmus Campestris.* This is a strong durable timber of a reddish brown colour, very cross grained and difficult to work. It is used in the old countries in positions subject to permanent wet

385. TEAK. *Tectona Grandis.* An excellent timber with a straight grain possessing great strength and is of great value in construction. It is somewhat like oak, but darker, the colour being brown. It is sold in the English market in logs from 10 to 30 inches square and from 20 to 40 feet long. It grows in Southern Asia.

386. BEECH. *Fagus Sylvatia.* A hard, compact, fine grained, timber very tough, but not difficult to work. It is not used much in building construction, but is a notable timber to builders on account of the extensive use of it in all kinds of wood-working tools. In cabinet work it looks well

387. WALNUT. The two species best known to commerce are COMMON WALNUT, *Juglans Regia*, and BLACK WALNUT, *Juglans Nigra*. The former is found in, Europe. It is a solid compact wavy grained timber, which does not twist or warp. Black Walnut is an American timber, very beautiful in appearance, the colour being dark purple or violet which however becomes very dark as the timber ages. These timbers are expensive and are only used in cabinet work.

388. ROSEWOOD. *Dalbergia Nigra* is a timber obtained from Rio, Bahia, Jamaica, and Honduras. It is of a deep ruddy brown colour richly streaked and grained with black resinous layers and takes a fine polish, but, it is somewhat difficult to work on account of its resinous nature It is sold in half round logs 5 to 2 inches at thickest parts by from 10 to 20 feet long. The use of Rosewood is confined to cabinet work.

389. MAPLE. Common Maple. *Acer Campestri*, and Bird's Eye, Maple *Acer Saccharinum.* Common Maple is a European species of a whitish yellow colour and very fine grain. Birds' Eye Maple grows in America. It has a pretty appearance being studded at intervals with small brilliant looking knots, and the timber itself is of a whitish colour which turns to a rosy tinge on exposure to light. Maple is much prized for making into small pieces of cabinet work, and for inlaying panels, etc in joinery work.

AUSTRALIAN PINEWOODS.

390. THE following are those in use as building timbers :—

(1) Colonial Pine.
(2) Cyprus „
(3) Huon „
(4) Brown „

KAURI PINE does grow in small quantities in Queensland, but what is used here is obtained from New Zealand, hence it will be taken under the head of Imported Pine Woods.

391. COLONIAL PINE. *Araucaria Cunninghamii.*—This timber is known in different places as "Colonial Pine," Morton Bay Pine, Richmond River Pine, and "Hoop Pine." It is of a pale yellow colour ; easily worked up ; and is durable if kept free from moisture. It is studded sparsely with very small round knots which give it when planed up the appearance of Birds' Eye Maple. Colonial Pine is used (especially in country places) for all kinds of building work, but more especially for flooring and lining boards, window frames, door jambs, shelving, and such internal work. Compared with the imported pinewoods it is not a first-class timber, but if it can be procured in a seasoned condition it is good and serviceable for internal work. It grows in abundance in Queensland and Northern New South Wales.

392. CYPRUS PINE.—Under this name are included a number of Pine timbers, the most valuable of which are :—

(a) *Callitrus Calcarata.*
(b) „ *Verrucosa.*
(c) „ *Columellaris.*

C. Calcarata, called "Cyprus Pine" "Black Pine," Red Pine," and "Murray Pine," is of a rich brown colour, with beautiful figuring. It is found from Northern Victoria to Central Queensland.

C. Verrucosa, called "Cyprus Pine." Black Pine," "Dark Pine and "Common Pine," varies in colour from a very light to a dark brown. It grows in all the colonies on the mainland.

C. Columellaris, called "Cyprus Pine" and "White Pine," is a fairly dark brown coloured timber with a silky grain, which grows in Queensland and New South Wales.

393. The Cyprus pines are valuable building timbers, being durable under reasonable conditions. Easily worked up to a smooth surface, and very beautiful in appearance. The knots, which are very plentiful, are in nowise defects, for, they do not become loose. Serious drawbacks of the Cyprus pine are brittleness

and inflammability, but against these disadvantages may be put the quality of being nearly impervious to the attacks of white ants. Cyprus pine is used for all kinds of joinery work, and in some cases for Cabinet work, for which it is well fitted provided that it is thoroughly seasoned.

394. (3) HUON PINE. *Dacrydium Franklini.*—An exceedingly durable and tough timber, of light weight, and pale yellow colour. It was much prized for joinery work but owing to an extensive use of it in the past it is scarce, and can, as a consequence, be seldom used except for Cabinet work for which it is well fitted. In first-class joinery work it is used for panels. It is a Tasmanian timber.

395. (4) BROWN PINE. *Podocarpus Elata.*—This timber known also as "White Pine," "She Pine," "Pencil Cedar," "Native Deal," and "Plum Pine." It is free from knots, fine grained, easily worked, and some of it is very beautiful in appearance. Its chief quality is its resistance to white ants and the *teredo*, and on this account is used for piles (see Art. 78 *ante*,) It is also largely used for all kinds of joinery work. Grows in New South Wales and Queensland.

IMPORTED PINEWOODS.

396. The following are the principal pine timbers which are imported and stocked by timber merchants :—

(1) Oregon Pine.
(2) Redwood ,,
(3) Baltic ,,
(4) Kauri ,,
(5) Clear ,,
(6) Pitch ,,
(7) American Spruce.
(8) Baltic ,,

397. (1) OREGON PINE. *Abies Douglaisi.*—This is a hard, rather coarse grained reddish coloured fir timber possessing a fair strength and is very durable. It is very extensively used about Sydney for scaffolding, beams, posts, joists, rafters, fascias, flooring boards and even in joinery work for window frames and sashes, and door jambs, etc. It is very resinous and consequently, on account of the exudation of the gum resin, it is not very suitable for good joinery work. It comes to the market in all sizes from 2″ x 1″ to 18″ x 18″ and in lengths of from 10′ to 70′. Generally speaking it is one of the most useful timbers in the market for general building purposes As a timber for use as scaffolding it is unequalled, being light and yet strong and capable of being obtained in long lengths. Oregon comes from the North West of America.

398. (2) REDWOOD. *Thuya Gigantea.*—This is a very soft, pithy timber, of a yellowish red colour. When dry it is very light, but is not strong. It is however very durable in exposed positions, and is, in consequence, an excellent timber for fascias, barge boards, louvres, shingles, weatherboards, and other such parts of buildings which are exposed to the weather, It is also much used for skirtings, architraves and mouldings and for window frames and sashes. It is an American timber which comes in sizes ranging from 1″ to 6″ thick up to 40″ wide and in lengths up to 20′.

399. (3) BALTIC PINE. *Pinus Sylvestris.*—This is a timber which grows in Northern Europe. That which comes to Australia is chiefly from Norway. It is a whitish, and slightly reddish yellow coloured timber, exceeding pleasant to work, fairly strong and tough, and durable if not put in exposed positions. The reddish tinted is called Red Deal, and the other White Deal. In, or about Sydney it is used only for joinery work such as window frames and sashes and doors, but, in Melbourne it is used very extensively for all kinds of joinery, skirtings, architraves, etc. In the Sydney market it is generally only obtainable in planks 11″ x 3″, and and in deals 9″ x 3″, in cross section, but in Melbourne it is obtainable in a much greater variety of sizes.

400. (4) KAURI PINE. *Dammara Australis.*—This is a New Zealand timber (though a little is found in Australia) of great value. It has a fine appearance when planed up, being free from knots, very fine grained, of a whitish yellow colour with a silky lustre. It is noted as being the strongest of the pine timbers, but it has a great fault inasmuch as it shrinks and swells with change of tempera-

ture unless perfectly seasoned. The grain is so close that it can be planed across the end as well as with it. It is consequently an excellent timber for turnery and carving, but is extensively and successfully used for flooring boards, door jambs, panels staircases, etc. A special use of the timber is for making wash tubs, bakers' troughs and other such utensils for which it is well suited for it does not stain when wet. It can be obtained in all sizes.

401 (5) CLEAR PINE. *Pinus Strobus.*—A white or pale straw coloured timber of light weight rather soft, and durable only in dry well ventilated places. It is considered to be a good timber for joinery work and is used for doors. The coarser grained kind is known as *Sugar Pine*, which is extensively used for stock made doors. Clear pine is an American timber. It comes in pieces 16′ long by from 1″ to 4″ thick and up to 30″ wide.

402. (6) PITCH PINE. *Pinus rigida.*—This is a resinous, hard, heavy, strong, durable timber free from knots, which is imported in small quantities from North America. It is suitable for flooring boards, but is used in the very best kind of joinery work.

403. (7) AMERICAN SPRUCE *Abies. alba*, *A Nigra*, *A Canadensis* and *A Rubra* is a tough timber full of glassy knots and liable to twist and warp. It is imported only in the form of shelving.

404 (8) BALTIC SPRUCE. *Abies excelsa.*—An inferior white timber full of knots which is used very much as lining boards.

TABLE XIX.

Showing Weight and Strength of Building Timbers.

No.	Name of Timber.	Weight per cubic ft. in lbs.	Modulus of rupture in lbs. per sq. in.	Resistance to crushing in lbs. per sq. in.	Classification.
1	Grey Ironbark.	73	17866	10165	Ironbarks.
2	Red „	76	16275	9281	
3	Blackbutt.	66	13728	7522	
4	Tallowwood.	77	15257	7585	
5	Spotted Gum.	62	13296	6753	Pale Hardwoods.
6	Grey Box.	73	16209	8021	
7	Stringy Bark.	71	13931	5985	
8	Mahogany (Red).	75	14500	7511	
9	Grey Gum.	57	13092	7243	
10	Red Gum.	62	6930	5016	
11	Sydney Blue Gum.	69	12023	5889	Red Hardwoods.
12	Woolybutt.	63	12708	6981	
13	Jarrah.	63	10800	7000	
14	Turpentine.	69	11727	6364	
15	Cedar.	35	7400	3600	
16	Rosewood.	74	10594	6011	
17	Colonial Beech.	63	15607	8253	Australian Softwoods
18	Blackwood	70	10264	6784	and figured timbers.
19	Forrest Oak.	75	15492	8335	
20	Teak Native.	62	14415	7030	
21	English Oak.	49	12000	10000	
22	American Oak.	61	10000	6000	
23	Mahogany (Spanish)	53	7600	7168	
24	Mahogany (Honduras)	35	11500	6018	Imported Hardwoods
25	Ash.	43	12000	9000	and figured timbers.
26	Elm.	34	6000	10300	
27	Teak.	46	18000	12000	
28	Beech.	43	9000	9360	
29	Walnut.	43	—	—	
30	Maple.	42	—	—	
31	Colonial Pine.	54	8824	4199	Australian Pinewood.
32	Kauri „	34	11000	5824	
33	Baltic Pine.	30	7100	5500	
34	Redwood.	24	6000	5200	Imported Pinewoods.
35	Oregon.	32	7900	5700	
36	Pitch Pine.	41	14088	6720	

405. Strength and Weight of Timber.—The table XIX. has been compiled to illustrate the weight and strength of the various timbers used in building construction. Many of the timbers described in the preceding articles are omitted from the table; in some cases because authentic tests are not obtainable, and in others for the reason that the timbers are not used for other than delicate joinery or cabinet work, where weight and strength are not matters affecting their use. The tests Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 11, 12, 15, 16 17, 18, 19 and 20 are extracted from Professor Warren's valuable work on *The Strength and Elasticity of New South Wales Timbers*; the others are from Rankine's *Civil Engineering*, Molesworth's *Pocket Book of Engineering Formulæ* and Rivington's *Notes on Building Construction*.

406. Cutting of Timber.—Economy of course demands that a log shall be cut up so as to get from it as much timber as possible, but this does not mean that the log shall be simply divided into the greatest number of pieces without any regard to other matters. The use to which the timber is to be put should be considered, and unless this is done the value of the timber is greatly interfered with. When the timber is to be used in work where the strength is a matter of importance, then the cutting up of the log should be such as to get the strongest pieces. Again, where the timber is to be used in such as joinery or cabinet work where appearance is of consequence, it is necessary to cut it so that the most beautiful grain shall show; or it may be necessary, as is sometimes the case, to get surfaces which will be the most easily worked. And, these are matters affecting the user just the same as the saw miller, for the architect or builder should see that he gets the strongest, or prettiest, or most easily worked timber, as the case may require. This article is to deal with these matters, and to begin with it is necessary, with a view to a proper understanding, to briefly describe the structure of trees. From the centre to the bark is composed of a mass of wood fibre which is arranged in concentric layers—

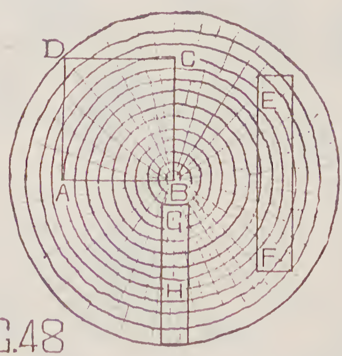


FIG.48

there being one layer for each year of growth of the tree. These layers are called "annual rings," and are generally distinct enough to be easily noticed. They are indicated on the sketch Figure 48 by the concentric wavy circles. Very thin partition-like layers radiate from the centre towards the outside of the tree, passing through and dividing the annual rings into segments. These radial partitions are called medullary rays. They are illustrated by the lines radiating from the centre to the outside on the sketch Figure 48.. In some timbers, such as English Oak, they are very distinct; in others they are not so easily discerned. Timber shrinks mostly in the direction of the annual rings, consequently if a piece of timber square in cross section with the rings in it as at A, B, C, D, Figure 48 be cut out and left to season it will shrink most in the direction of the rings, so that the corners A and C will be brought closer together, while the distance from B to D will be very little altered. Planks cut with the rings roughly in the direction of the depth as E, F, Figure 48, will be stronger than if cut as at G and H with the

rings at right angles roughly to the depth. In many cases the prettiest grain is obtained by cutting as E and F with the sides of the rings showing on the surface, but where the medullary rays are large and distinct a ve y beautiful grain called silver grain is o tained by cutting them obliquely as at G and H. Figure 48. When cut this way the rays are exposed sideways at the surface, and give a pretty effect. In many caseses the grain is more easily worked where the surface is formed by the edges of the rings as at G and H, Figure 48.

CHAPTER XI.

CARPENTRY AND JOINERY.

407. **Carpentry** is distinguished from joinery as being that part of the timber work which is directly connected with the stability of the building, as for instance, the floors and roof; while the **joinery** consists of the doors, windows, stairs, trimmings, fittings, etc. The joints in carpentry are, however, closely related to those used in joinery, consequently it will be convenient to take together, and describe, the principal joints used in the two classes of work.

JOINTS.

408 **Lapping** consists of putting the ends of the two pieces of timber, one over the other, as shown at A, Fig. 48A and securing them together with bolts only, or with bolts and straps This joint is, however, ugly on account of the want of appearance of continuity in the pieces as joined. It is, moreover, not suitable for tensional or compressive stresses.

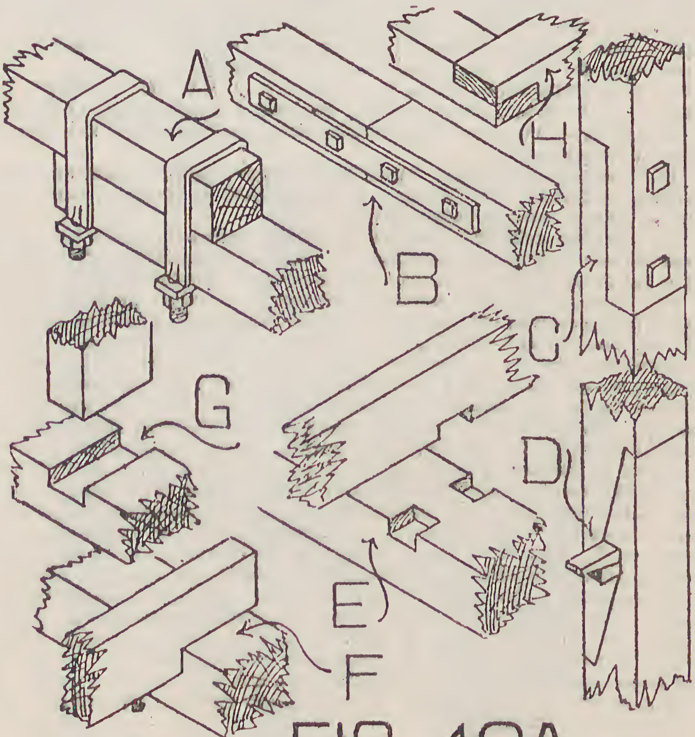


FIG. 48A

409 **Scarfing** is a better form of joint inasmuch as it gives the appearance of continuity, and can be made to suit either compressive or tensile stresses. The joint at C, Fig. 48A, shows a scarfed joint for compressive stress. In this case the

two pieces are cut one into the other, so that the whole of the resistance of the fibres is available against compression, while it is not unsightly by any means. The two pieces are held together by bolts, or by bolts and straps. The example D, Fig. 48A, illustrates a case of scarfed joint for tensional stress, with an arrangement of wedges in the centre for tightening up the joint. In cases where extra strength is required straps and bolts are added. At times very complicated scarfed joints are made with a view to increased strength, but, without altogether condemning these, it is well to remember that simple joints are the easiest to make with accuracy, and consequently are the best, and indeed it is seldom that the exigencies of building work require more than the two cases given above.

410. FISHED JOINT.—A useful joint for timbers in compression is that known as the "Fished Joint." This is shown at B, Fig. 48A. As will be seen it consists of butting the ends of the pieces together, and securing them in position with side plates of iron bolted together. In cases where clumsiness is not an objectionable feature the side plates may be of timber. It will be noticed that a scarfed joint with side plates and bolted together is a combination of scarfed and fished joints.

411. HALVING is a joint much used in building work. It consists of cutting half out of each piece for a distance equal to the width of the timber. See H, Fig. 48A. It is used for joining wall plates, etc.

412. NOTCHING. A notched joint is made by cutting a bit cut of one piece, so that it may fit over the other, and obtain a shoulder hold as at F. Fig. 48A. When a bit is taken out of each piece the joint is known as "*Double Notched*." Both of these joints are much used in flooring and roof work.

413. COGGING consists of the form shown at E, Fig. 48A, which is a kind of notch. As will be seen the notch does not extend right through, but a bit is left in the middle in one piece. This joint is suitable, and is much used, for jointing joists on to girders.

414. HOUSING, shown at G, Fig. 48A, is a simple way of connecting the end of one piece with the side of another. It is much used in floor and roof work and also in joinery work to some extent.

415. MORTISE AND TENON.—This joint, like housing, is used for connecting one piece endwise with the side of another. There are many forms of this important joint, but the examples given will illustrate those in general practice. See Fig. 49. A is a tenon, B the shoulder and C the mortise. When the joint is near the end of the piece with the mortise, the tenon is cut back a little as shown at E, Fig. 49, the shortened part of the tenon being called the "haunch." The haunch preserves the strength at the root of the tenon, and avoids cutting the mortise right up to the end of the other piece. The ordinary mortise and tenon joint is fastened by driving wedges in at each side of the tenon at the back of the mortise. (See H, Fig 49.) Of course this is not possible where the mortise does not go right through. In the latter case wedges are put in at end of tenon before the latter is inserted in the mortise. Then, as the tenon is pushed in the wedges are driven home by being pushed against the bottom of the mortise. (See F, Fig. 49.) The wedges extend the end of the tenon, and so prevent it from coming out. Such are called "Fox wedges." An important form of mortise and tenon is shown at K, Fig. 49. This is known as the "tusk tenon," and is used for jointing joists with joists, and joists with girders, so as to weaken the timbers as little as possible by the mortise, and yet get the strongest possible hold by the tenon. The proper proportion is to have the shoulder S $\frac{1}{6}$ of depth of joist; the depth W of tenon also to be $\frac{1}{6}$ of the depth of joist; and the bottom of the tenon should be just at centre of the beam with the mortise in it. Where possible the tenon should be carried through the beam and secured with a wedge. If this cannot be done the tenon should be held in place by a pin driven from the top of the beam down through it.

416. BUTT JOINT.—This term is given to the joint made when one piece is butted on the end of another as shown at O, Fig. 49. It is also the joint when boards are joined together by planing and shooting, and sometimes glueing the edges, as at N, Fig. 49. In the rough kinds of flooring the boards are merely placed edge to edge and nailed. This would be known as butt jointing. The butt joint can be much improved by inserting tongue pieces or "slip feathers" in grooves run along the butted edges. (See example N, Fig 49.) The joint is much

stronger if the grain of the slip feathers is crosswise. A right angled butt joint beaded with return bead is shown at I, Fig. 49.

417. GROOVED AND TONGUED JOINT.—This form of joint is used for joining flooring and lining boards, and in many parts of joinery work. It consists of forming a projecting slip or tongue a'ong the edge of one piece. and a groove into which the tongue will accurately fit. along the edge of the other. (See U, Fig. 49.) The tongued and grooved joint is also used often for joining pieces at right angles. (See D, Fig. 49A, which illustrates metho l of joining a board at right ang'es to another.

418. MITRE JOINT.—This joint is illustrated at R, Fig. 49. It consists of joining two pieces so that the line of meeting, or the joint, forms a bisection of the

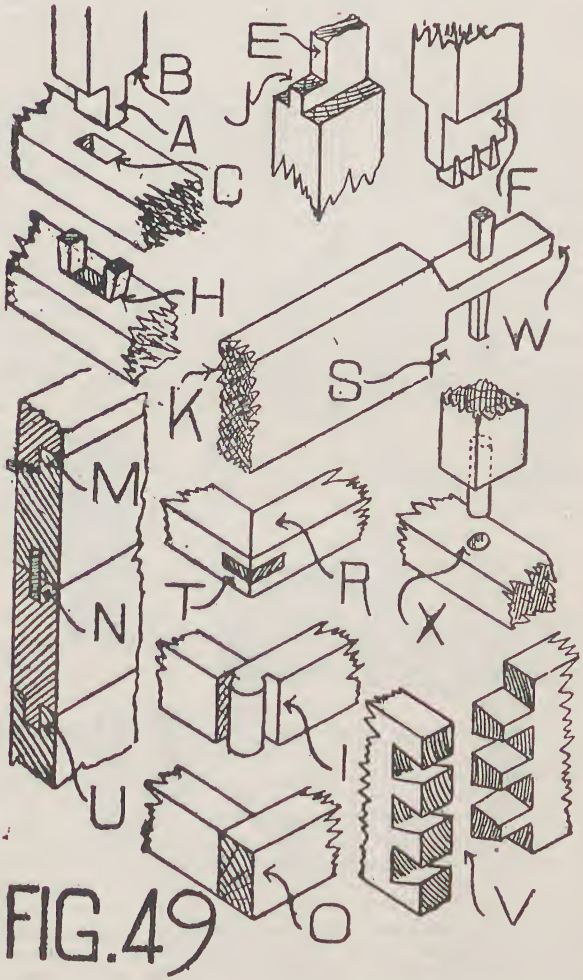


FIG. 49

angle at which the two pieces meet. The pieces are held together by nails in rough and external work, and by glue in the lighter work of joinery. Sometimes a thin slip of wood called a "key" is cut in across the angle as shown at T, so as

to strengthen the joint. The mitre is used occasionally in conjunction with other joints, as, for instance. the rebate. the tongue and groove. the dovetail, etc.

419. REBATE JOINT.—Consists of rebating each of the edges to be joined so that they lap into each other as at M. Fig. 49.

420. DOVE-TAILED JOINT.—In this kind (see V. Fig. 49) tenons or "pins," (shaped like a bird's tail extended) on one piece fit into mortices or "sockets" cut out of the other piece. The spaces between the pins should be equal to the size of the pins, so as to make the strongest joint. The *Dove-tailed joint* is useful for joining at right angles, the edge joists of suspended landings, verandah plates, etc., in carpentry work; but it is more particularly suited for the better class of joinery work.

421. DOWELLED JOINT.—This joint is really a mortise and tenon joint, in principle, as will be seen by X, Fig. 49 which shows a dowel. and socket for same. It consists of a pin, which is usually of some hard wood, but sometimes of metal, inserted into each piece joined together. It is used generally in connection with the butt joint,

422. END BUTT AND KEYED JOINT is shown at A, Fig. 49A. As will be seen this consists of securing two pieces end to end with a sort of wooden clamp or "key," as it is called, which is a narrow tongue passing from one piece to the other and having enlarged ends (B) to form a hold in each. The joint is tightened up with wedges inserted at shoulders (E) nearest to the joint. This joint is used for securing segments of curved sashes, etc.

423. END BUTT JOINT WITH CONNECTING SCREW.—A joint to serve the same purpose as above is often made in hand-railing work. The ends are butted together as shown at A. Fig. 49A but instead of the key a metal screw, with threads at both ends, is inserted, and, by means of this screw the joint is tightened. The best kind of screw has nuts at both ends. These nuts are put in and tightened up through mortises at sides and near the ends of the pieces joined.

424. SCRIBED JOINT is used principally for joining mouldings in internal corners where it would be difficult to get a mitre joint tight. By reference to C, Fig. 49A, it will be seen that the end of one piece is cut out so as to be the exact

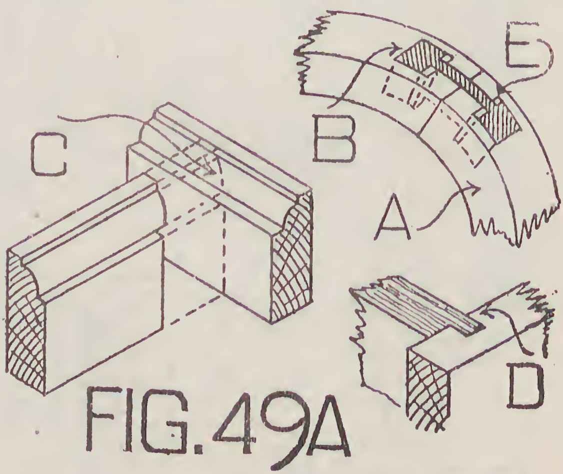


FIG. 49A

reverse of the face of the other, and when pushed tight up against it the joint will be a perfect intersection. From the outside it has the appearance of a mitre joint. Scribing, however, in a more extended sense, is the term applied to all joints in which one piece is marked and cut, so as to fit accurately up against another piece, or wall, with an uneven surface.

CARPENTRY.

FLOORS

425. STOREY POSTS AND GIRDERS.—The storey posts are the timber columns or uprights which support girders carrying floors or walls In the sketch Fig. 50,

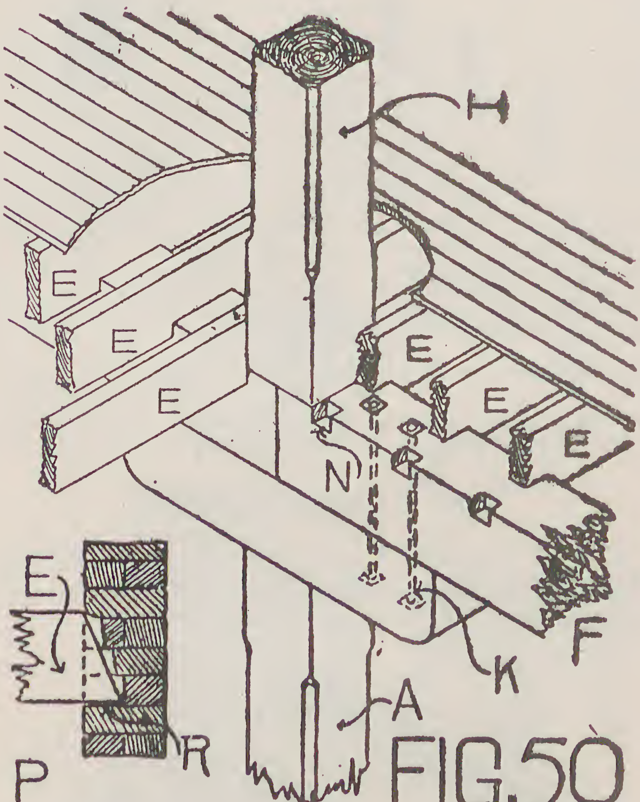


FIG. 50

a storey post (A) is shown supporting two girders jointed together over its head and with the super structure of joists, etc., and another storey post to support an upper floor. This is a typical example of factory or warehouse floor construction. The posts are spaced from 16 to 20 feet apart, while the girders are placed from 10 to 15ft. apart. In Fig. 50 the girders are shown butt jointed and to improve their bearing a cap or " bolster " piece is put extending for some distance under them on top of column. The girders are bolted to the bolsters as shown at K, while the head of the post is secured to bolster with a mortise and tenon joint. In the case of a post resting on the ground the foundation is made with a block of stone supported on brick in cement or concrete foundations, the foot of the post being tenoned or dowelled in the stone. Upper storey posts are tenoned into the girder on which they rest. In some cases, as for instance shop and office buildings, where the girders are to be cased in, the bolsters may be considered objectionable in appearance and consequently omitted, the girders being allowed to rest on top of column. Where joints occur, in such cases, a scarf after the

style of that at D, Fig. 48A, should be made or perhaps better still the butt joint improved, as at B, Fig. 51, with flush fish plates. In Fig. 51 the storey post and girders are shown as dressed and cut to illustrate a method of finish in cases where appearance is a matter of importance. Care should however be taken not to cut too much away from the post, as there is danger of rendering it incapable of sup-

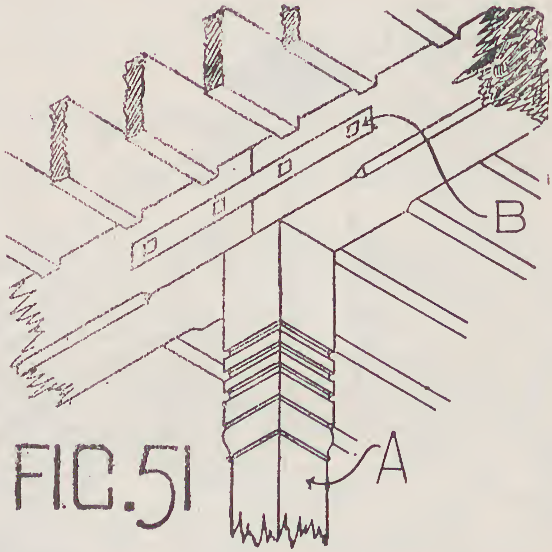


FIG.51

porting the load to be put on it. For this reason some architects insist that nothing shall be cut from the post, but that whatever moulding there is to be done shall be *planted on* and not *cut into* the post, thereby preserving all the timber for resistance to the stresses. In any case, of course, it should be provided that

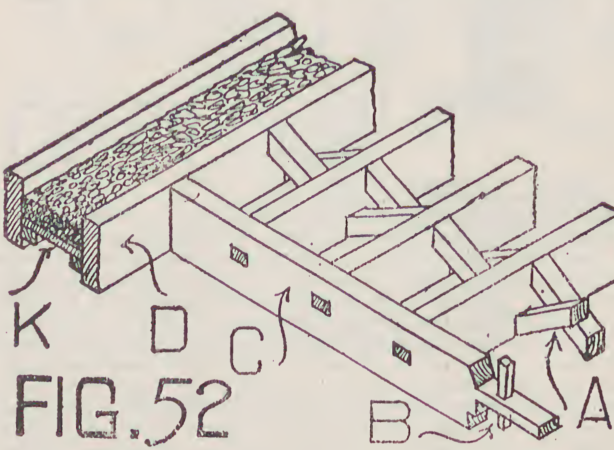


FIG.52

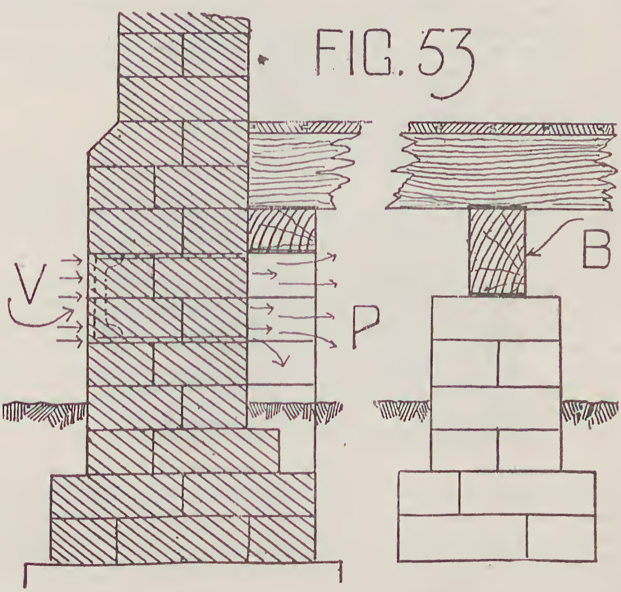
he least cross section of the post shall be sufficient for strength required. In the rougher, or mill construction, where strength is the main object in view, the posts

and girders are not as a rule dressed but are left as from the adze or saw, the 'arrises" or sharp edges only being removed. A rough stop chamfer is sometimes put on. Whether rough construction or not, the bearing surfaces should always be dressed so as to render them perfectly even and true. When setting the storey posts in position the greatest care should be taken to have them perfectly upright and that all bearing shoulders be quite horizontal. The girders should be quite level, and the ends in walls should bear on template stones. (See M, Fig. 47, and Art. 313, ante.) The brickwork or masonry of the wall should not be built close up round end, sides, and top of part in the walls, so that there may be an access of air to prevent dry rot This provision is also of value in case of fire, where the burning girders may fall out of the walls without pulling the latter down, as would be the case if they were tightly secured. Storey posts and girders, though sometimes of imported pine, are generally of Australian hardwood; the best for the purpose being ironbark. In much of modern work the columns are of cast iron, hollow and circular in cross section, fitted with box-like caps which are a combination support for girders and upper storey posts. These will be dealt with later on. In cases where the best beams available are not sufficiently strong to carry the loads to be borne it becomes necessary to artificially improve their strength. The simplest way to do this is to cut the beam into two equal pieces (cutting in the direction of the depth and length). The flitches are then reversed (that is to say, the outer sides are placed so as to be inwards), and an iron or steel plate about ½ inch thick (or as the case may require), and of the length and depth of the beam is put between them and the whole bolted together. Instead of the iron plate, iron trusses composed of struts, tension piece, keybolt and abutment connections are sometimes bolted in. In other cases metal tie rods are used.

426. JOISTS are the pieces of timber on to which the flooring boards are nailed and which support the ceiling material.

427. JOISTS FOR FLOORS NEAR THE GROUND are supported at the ends near the walls by plates of hardwood, generally 4″ x 3″ in cross section, which are set

FIG. 53



on to 9″ x 4½″ brickwork piers which project from and are bonded to the foundation walls and spaced not more than 36″ apart. One of these piers is shown at B Fig. 35 *ante* and at P, Fig. 53. Sometimes a projection 4½″ out from foundation

wall is carried right along and so gives a solid bearing throughout for the plate. An example of the latter is given at A, Fig. 35 *ante*. It will be seen that by having these piers, or the plate wall, the building of either plates or ends of joists in the wall is avoided, and this is an important matter, for timber should not if possible be built in brick or masonry walling. Hardwood bearers of about 6" x 3" arranged under joists parallel with plates should be set at intervals apart of not more than six feet, see B, Fig. 53. These bearers should be supported by brickwork piers, about 9" or 14" square in cross section, and spaced not more than 48" apart. When bearers, as above, are set under the joists the spans would not be more than 6 feet, consequently the joists need not be more than 5" x 2½" in cross section. In most cases the joists are slightly notched, as required, on to plates and spiked. The joists are generally spaced 18" centre to centre, and, for finish round hearths, etc. plate walls should be built for reception of plates for necessary bearing of ends of joists. Plenty of space should be left under lowest parts (bearers and plates) of ground floors, and through currents of air should be provided for by plenty of ventilators, an example of which is shown at V, Fig. 53. Australian hardwood (such as tallowwood) is the best to use for plates, bearers and joists of ground floors ; and as a preservative against vermin, such as white ant, the whole lot should be well soaked with kerosene (waste) tar.

428. Joists for Floors of Upper Stories.—The joists of floors for upper stories, and for ground floors with basements, are generally arranged with as long spans as possible to avoid the inconvenience of upright supports. In ordinary dwellings the walls of the rooms are not, as a rule, too far apart to allow of the joists spanning the distance ; but in large rooms, and in factories, warehouses, hotels, public buildings, etc., the rooms are often very large, and it is impossible to have joists in one span over them, and girders (often with columns) are necessary.

429. To describe these different cases it will be best to divide them as follows :—

(a) *Joisting of ordinary floors over spaces of small area requiring only short spans.*

(b) *Joisting of floors supported at intervals over spaces of large area which it would be impossible to span with single joists.*

The latter class may be sub-divided as follows :—

(1) *Joisting supported by girders.*

(2) *Joisting of double floors.*

(3) *Joisting, etc., of framed floors.*

430 (a) Joists of Ordinary Floors.—In common work (where the span does not exceed 18 feet) the joists are put in single pieces extending from wall to wall. When a ceiling is necessary they also serve to carry it ; the laths or metal being nailed to their bottom edges. A sketch of part of an ordinary floor is shown in Fig. 52.

431 (b1) Joists Supported by Girders.—In this kind the floor is really a case of an ordinary floor, as far as the joists go, but, the span would be too great for the joists themselves, and the support of girders would be necessary.

An example of joisting supported by girders is shown by Fig. 50. The joists would be *double notched* or *cogged* on to the girders. The spaces between the girders are called *Bays*, and when ordering the joists it is well for the purpose of tieing the lot together to have some of the joists in lengths long enough to reach over a couple of bays. Like case (a) the joists would be required to carry the ceilings.

432. (b2)—Joists of Double Floors—The joisting in this kind is supported at intervals of not more than 6ft. by small girders called "binders;" but the ceiling would not be carried by the floor joists—a separate set of under joists (called ceiling joists, and secured by cutting on to fillets or by nailing to bottoms of girders), being provided to carry the ceiling. By this means the vibration of the floor is not so easily communicated to the ceiling, and the chances of the plaster being cracked and loosened are reduced. It will be noticed that the binders are not introduced so much for support to joists as for separating the latter from those to carry the ceiling.

433. (b3)—Joisting, etc., of Framed Floors.—This class is really an elaborate kind of double floor the principle (viz., separate joists for floor and ceil-

ing) being the same; but for a big span the binders would not be sufficient support, and girders are introduced to carry the binders, which in their turn carry the floor and ceiling joists as described in preceding article. In Fig. 54 is shown the section of part of a Framed floor. E E are the floor joists cogged or

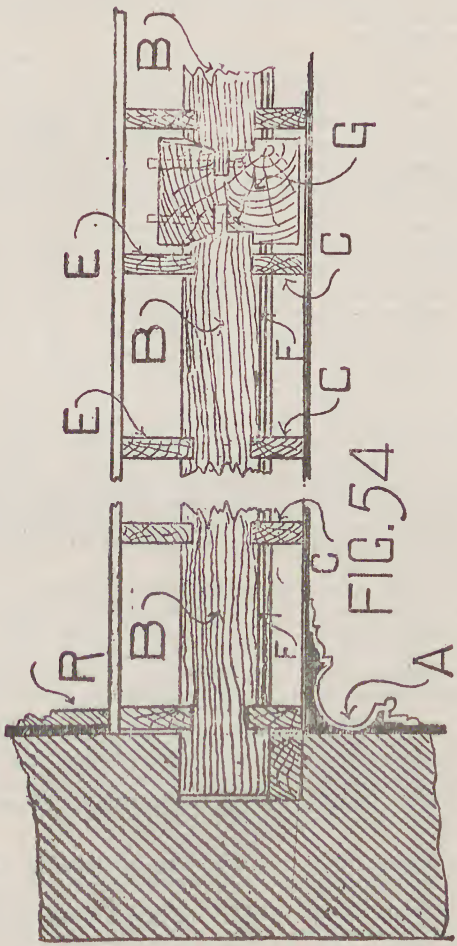


FIG. 54

doubled notched to the binder (B); C C are the ceiling joists cut on to fillet (F) at side of binder (B). The binder (B) is shown, by a side view, tusk tenoned into the girder, an end section of which is shown at G.

434. Double and Framed Floors are hardly to be recommended, as they have a lot of timber in them and they lose all stiffness if there is the least shrinkage of the timber of girders or binders. In these days so much iron and steel is used in floor and ceiling work, with such good results—especially if proper fire-proofing provision is made—that heavy framed timber floors are out-classed altogether. The same cannot be said of the single floor supported on Hardwood

girders and storey posts. The construction is simple, giving strength and stiffness and also very effective fire resistance.

435. The following articles, 436 to 440, deal with matters relating to upper floor joisting generally, irrespective of the kind of floor :—

436. SPACING APART OF JOISTS —Joists are usually spaced 18in. from centre to centre. When floor joists are to take plaster ceilings this spacing is necessary as the laths generally used are cut in lengths of 4' 6''. Joists are, however, sometimes 12'' and 15'' centre to centre.

437. BEARING OF JOISTS IN WALLS.—The end bearings of joists in walls should not be less than $4\frac{1}{2}$ inches, and they should be notched on to wrought iron plates (see R, Fig. 50) about $2'' \times \frac{3}{8}''$ in cross section. It is best to have the ends of the joists cut on the bevel, as shown at P, Fig. 50. If cut this way, less of the brickwork is interfered with, and in the event of fire the burning joists may fall out without damaging the walls, as they would, by leverage, if square ended.

438. TRIMMING.—Where openings, such as hatchways and stair well-holes, are to be formed in the floors, the ends of the joists cut through are "tusk" tenoned into a supporting cross piece called a "trimmer," an example of which is shown at C, Fig. 52. The trimmer should also be tusk tenoned (as B, Fig. 52) into each of the two long joists called *trimmer joists* (one is shown at D in Fig. 52) at the sides. Since the trimmer and trimmer joists have to carry the weight of the load on the trimmed joists, as well as on themselves, they should be stronger than the common joists. As a rule, they are made from $\frac{1}{4}''$ to $\frac{1}{2}''$ thicker, as the size of the opening may render necessary. Floor and ceiling joists should be trimmed round all fireplaces and flues. (See Art. 211 & 212 ante in regard to flues).

439. STRUTTING.—To increase the stiffness of the floor the joists should be "strutted," or, as it is sometimes called, "Bridged" This is done either by "*herringbone*" or *solid strutting* The former consists of $2'' \times 2''$ Pine or Hardwood cut in between joists in lattice fashion as shown at A. Fig. 52. The solid strutting is composed of pieces of board about $1\frac{1}{8}''$ thick and about the same depth as the joists. These pieces of board are cut in vertically between the joists and kept in rows. Great care should be taken that all the strutting, whether herringbone or solid, is well nailed to the joists. Each lot, or bay, of joisting should have rows of strutting spaced not more than 5' apart.

440. PUGGING.—With a view to preventing the passage of sound from one storey to another, through the floors, boarding about 1'' thick is put in, horizontally, resting on side fillets (see K, Fig. 52) between the joists. On the top of the boarding is put the "pugging." This may be composed of either (1) Coarse hair mortar; (2) Lime mortar and smith's ashes; (3) Lime mortar and chopped straw; or (4) Shavings which have been well steeped in hot lime.

441. WEIGHT TO BE CARRIED BY FLOORS.—The table XX. gives the weight, per square foot of area, carried by floors in different kinds of buildings. In special cases such as factories where there is heavy machinery, or, in warehouses where the stock is of a particularly heavy character, the weight per square foot should be ascertained by experiment.

TABLE XX.*

Showing weights under ordinary circumstances on floors in different kinds of buildings. The weight (approximately) of floor is included in each case.

Kind of Building.	Weight per foot superficial in lbs.
Ordinary Dwelling Houses ...	140
Public Buildings	168
Warehouses, Factories, etc. ...	280 to 448

*Hurst.

442. SIZES OF COMMON JOISTS.—So that safety may be arrived at with economy, it is best, especially in cases where large quantities of timber are involved, to calculate the sizes of the joists to suit the conditions of load to be borne by the floor under process of design. Joists should be calculated as bearers with a distributed load. Particulars as to how to do this will be given later on. It is however, hardly necessary to go to the trouble of determining the sizes in cases

of ordinary floors, because experience provides plenty of information in this respect and it is best to follow the general practice. Table XXI. gives usual sizes of common joists of pine. The different kinds of Australian hardwoods (See Arts. 329 to 354) are stronger than pine and well suited for joists, and if used, the size may be a little smaller than those given in the table, but care must be taken that the hardwood is dry, for, unless quite seasoned, it would be unwise to reduce the size. The Oregon Pine, to which the Table may be applied, is much used, and is a very suitable timber for joisting.

TABLE XXI.*

Showing Suitable sizes of pine common joists for ordinary floors. Joists to be spaced 18″ centre to centre.

Breadths in inches.	1½	2	2½	3	4
Length of Span in feet.	Depth in in.	Depth in in.	Depth in in.	Depth in in.	Depth in in.
6	7	6	—	—	—
8	8	7	—	—	—
10	9½	8	7½	—	—
12	10½	9	8½	—	—
14	11½	10	9½	—	—
16	12½	11	10½	10	—
18	—	12	11½	11	—
20	—	13	12½	12	11
22	—	—	13½	13	12

*The depths given in the table are in most cases not the exact results of the calculations, the intermediate fractions being raised, for the sake of convenience in practice, to the ½ or full inch as the case required.

443. Flooring Boards.—These are the pieces of timber, laid all over and secured to the joists, to form the upper surface of the floor. The boards are by no means an unimportant part of the whole floor, and to have them of suitable quality, thoroughly seasoned, and well laid, is of great importance; in the first place because unless strong and durable they will be quickly worn out; and in the next if not well seasoned and skilfully laid they will shrink and split, and the interstices so caused will be receptacles of dust and filth, causing danger to health.

444. Timber for Flooring Boards—Tallowwood and Colonial Beech are the best of the Australian timbers for flooring boards. Colonial Pine will also do well but should not be used in preference to the timbers mentioned above. Of the imported timbers, Kauri, Oregon, Baltic and Pitch Pine do well for flooring As before remarked it is of the utmost importance to have the timber for flooring well seasoned, and with a view to having it dry, it should be brought if possible on to the site and stacked as soon as the building is commenced.

445. Size of Floor Boards.—Flooring boards should be as narrow as possible, so as to reduce the tendency to shrink. 4″ is a good width, but they should under no circumstances be wider than 6″. The thickness ranges from ⅞″ to 1½″; the thickness most generally used for ordinary work being 1″.

446. Joints of Flooring Boards—These may be divided into two kinds, viz.:—

(a) Longitudinal Joints.
(b) Cross ,,

447. The longitudinal joints are those made by the boards sideways with each other. The cross joints (or "heading" joints as they are called) are those made by joining piece to piece endwise in the length. The longitudinal joints are made either as:—

Plain Butt Joint.
Or *Ploughed and Tongued Joint.* See N, Fig. 49.
,, *Rebate* ,, See M, Fig. 49.
,, *Tongued and Grooved* ,, See U, Fig. 49.
,, *Secret Nail Joint*, as at A, Fig. 55.

The tongued and grooved joint (U, Fig. 49) is the one most used in practice for ordinary work. Care should be taken that the groove is not too near the upper surface, for, if it is the board will very soon be worn down to the groove and rendered useless. The shoulders of the tongued and grooved edges should be quite

square with the faces of the boards, and the tongues should be a little less than the depth of the grooves, so that the boards may be brought tight up against each other with the cramps which latter are screws temporarily attached to the joists and used for pushing the floor boards tight together before being secured. In ordinary work the boards are secured to the joists by nailing with two nails, into each joist, along the length of each board. The nails should be punched in. and unless in very common work, the holes well stopped with putty. In first-class work the nail holes, even if stopped with putty, a e objectionable in appearance, and the secret nail joint shown at A Fig. 55 is used. In this case one board is laid at

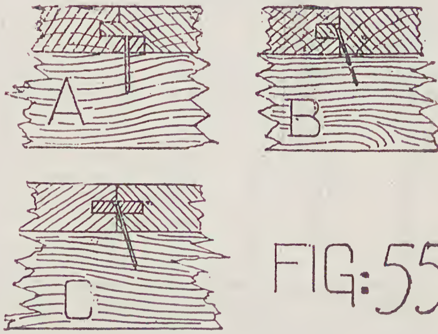


FIG: 55

a time and nailed at outer edge, the other edge being caught in the groove of last laid board. As will be seen, the nails would be hidden from sight. The tongued and grooved joint may, however, be laid with hidden nails, as shown at B, Fig. 55.

448.—The heading joints should break with each other, and are made either by :—

Plain Butt Joint,
Or Bevelled „ „
„ Ploughed and Tongued Joint.

All joints, of course b ing on joists. Care must be taken to have the boards so joined exactly of the same width, otherwise an ugly break and crevice will occur. This trouble is very likely to arise if the boards are mixtures of different "millings." For secret nailing the joint used would be the ploughed and tongued, as shown at C, Fig. 55.

449. PARQUET FLOORING consists of small pieces of fancy timber of different kinds inlaid as bordering into a first-class floor of boards ; or set close tog ther in geometrical design all over and supported by a strong foundation of ordinary flooring boards. The upper surface is generally polished, and, when well executed this kind of floor is not only very ornamental in appearance, but, very nearly approaches the ideal from a sanitary point of view, for, there are no cracks or crevices and consequently no harbour for dust.

Many of the Australian fancy figured timbers are eminently suited for this work. Parquet flooring may be obtained, made in squares all r ady for laying.

TIMBER ROOFS.

450. FORMS OF ROOFS.—The ordinary forms of roofs classified as regards outward appearance are as follows :—

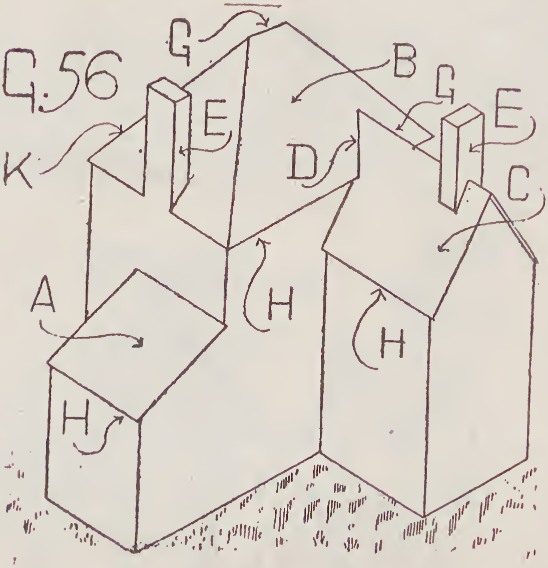
(a) Lean-to roof.
(b) Gable „
(c) Hipped „

There are other special forms such as Mansard, Curved roofs of all kinds, and Domes, but more than a very brief reference to these, at a later stage, is impossible within the limits of these articles.

451 THE SKETCH FIG. 56 has been prepared to illustrate the ordinary forms of roofs. It is merely diagrammatic, and is not to scale.

452. (a) Lean-to Roof.—This kind (sometimes called a Skillion Roof) shown at **A** Fig. 56 is a simple form of roof suitable for small spans. As will be seen, it

FIG. 56



consists of one surface sloping down from back to front What is called a *V Roof* is formed of two lean-to roofs sloping down from the side walls to a gutter along the centre of the building. The details of a lean-to roof are shown by Fig. 57.

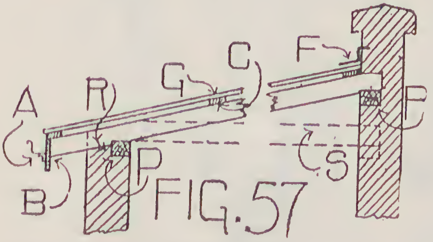


FIG. 57

Although sometimes the form of the lean-to is used for trussed roofs of a large span, (in which case the construction is complicated) the style of roof as illustrated by details in Fig. 57 is generally only used in rear buildings or verandahs where no ceilings are required. If a ceiling is needed the joists may be put in as shown by dotted lines marked S in Fig. 57.

453. Gable Roof.—The form of the gable roof is shown at C Fig. 56. It is a very common form, being used, perhaps, more than any other.

454. Hipped Roof.—This form is shown at B Fig 56. It may be described as pyramidal in shape, having surfaces sloping upwards from all the eaves, the salient intersections of the surfaces being called *hips*.

455. The forms of the two latter, viz., Gabled and Hipped Roofs, are produced by different methods of construction. The term *Gable* or *Hipped* is often replaced by that of the particular kind of construction. For instance, a Gable Roof may be built on the principle of the collar beam and may be called a collar beam roof, and so on.

456. The Different Methods of Construction are as follows :—

(1) Couple or single span.
(2) Collar beam.
(3) Couple close or tie beam.
(4) Truss.

457. (1) Couple or Single Span Construction is shown at W. Fig. 58, In this case the sloping surfaces are held in position altogether by the walls there being no cross tie in the roof itself. It is a weak form, for, there is an ever acting thrusting force against the walls tending to turn them over.

458. (2) Collar Beam Construction.—In this case, as will be seen by Z. Fig. 58, a horizontal tie piece, called a *collar beam*, is put in at some distance above the level of the top of the walls. This beam known also as a collar tie, helps to keep the two surfaces from spreading, and so, in a measure, relieves the walls. There is, however, a tendency to bend outwards of the parts of the rafters below the collar beam, and if this bending takes place the walls get an ugly thrust. To minimise the danger of bending, the collar beam should be as low as possible. In cases where a ceiling is attached to the collar beams the latter are generally called ceiling joists.

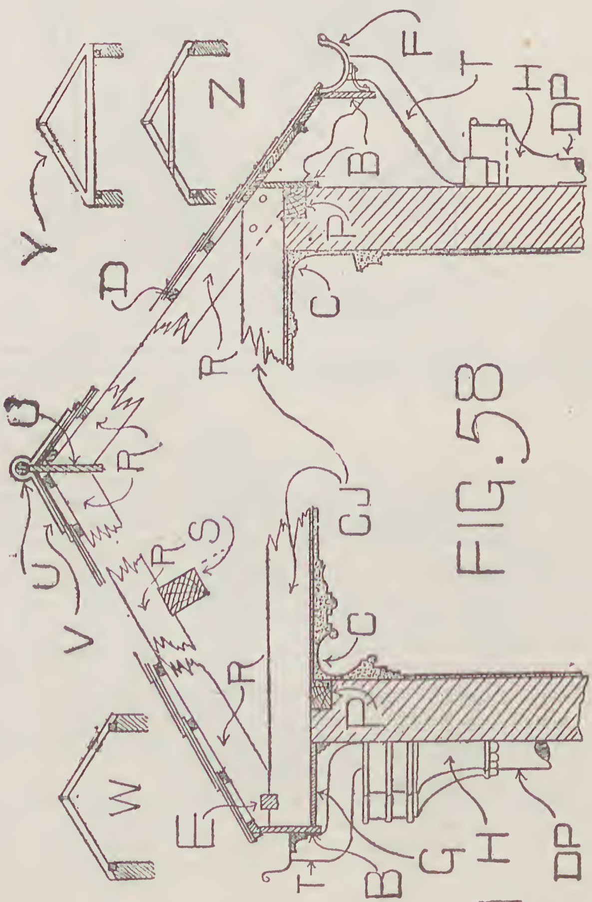


FIG. 58

459 (3) Tie Beam or Close Couple Construction.—This kind of construction, shown at Y, Fig. 58, is most generally adopted for roofs where the span is not great enough to render truss construction necessary. As will be

seen by the drawing, the tie beams (really the ceiling joists) are put across at the level of the top of the walls, and are secured to the feet of the rafters. Different methods of securing the ceiling joists to the feet of the rafters are shown in detail in Fig. 58

460. (4) Truss Construction.—The kind of construction noticed in the last article does well for roofs of span up to about 16 or 18 feet, but, when over 18 feet it is altogether unsuitable, as the system is deficient in stiffness and it becomes necessary to sub-titute what is called Truss Construction, which consists of supporting the rafters on braced frames, spaced about 10 feet apart. These braced frames, which also serve to carry the ceilings, are called "trusses" or "principals." Two kinds of trusses are shown by Fig 59 The top one is known as a *King Post Truss*, and is suitable for spans up to 30 feet.

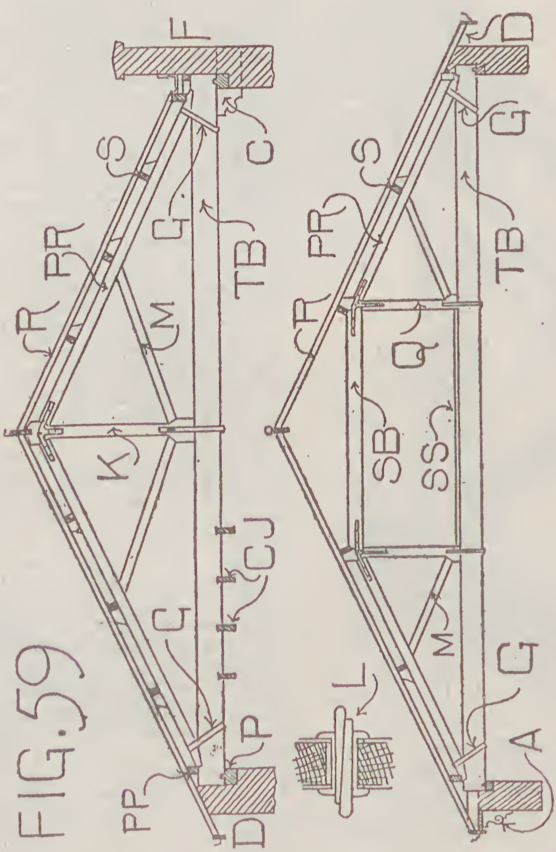


FIG. 59

461. The King Post Frame consists of :

Tie Beam	marked	T B	Fig. 59.
Principal Rafters	„	P R ·	„
King Post	„	K	„
Struts	„	M	„

462. Pieces of timber called *Purlins* stretch from frame to frame and on these the common rafters are secured. One purlin is marked S in Fig. 59. The

functions of the parts of the frame are as follows :—The Tie Beam acts as a tie and prevents the principal rafters from spreading outwards at the feet. The King Post acts as a suspender to hold the centre of the Tie Beam up and so prevents "sagging" of the latter; while the struts serve to support the centres of the principal rafters. The combination of parts is therefore such, that all are acting together to resist change of form in the whole frame, and the result is a structure of considerable stiffness. A great deal, however, depends on the excellence of the methods of jointing the parts together, and these will now be dealt with.

463. Joints and Details of a King Post Truss.—Enlarged views or parts of a king post truss, together with other portions of a roof, are given by Figs. 60 and 61. The method of shouldering and tenoning the foot of a principal rafter into the tie-beam is shown in Fig. 61. To prevent the upper part of the end of the tie-beam being shorn off, the distance from the toe of the P R to the end of the tie-beam should be as long as possible; a good position is to have the toe just over the inside face of the wall, as shown by the sketches. An extra guard against the toe of the P R spreading is provided in the shape of the Heel Strap marked G in the sketches 59 and 61. This is composed of wrought iron, made with cover piece and screwed ends and nuts for fastening.

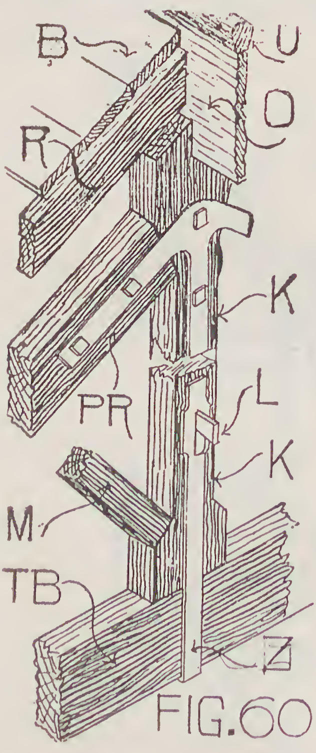


FIG.60

464.—The Heel Straps should be fixed at such an angle, that, in the event of being required to take up the stress by failure of the joint, they will be able to do so at once without allowing *any* spreading to take place.

465.—The King Post, which supports (as before pointed out) the tie-beam from the heads of the principal rafters, and also supports the centres of the latter per the struts, is shaped out of a single piece of timber, with enlarged base and head as shown in the sketches. The joint of the King Post with the tie-beam is made with a Stub tenon, and the two are kept together (for it is to be remembered that the tie-beam is pulling from the King Post) by the Tension or *Stirrup Strap* marked Z on Fig. 60. When the truss is completed the tie-beam should have a "*Camber*" *i.e.*, a slight upward curve. To bring this about the King Post is cut a little short, and the tie-beam is forced up to it by means of the pieces of iron called *Gib* and *Cotter* (marked L on Figs. 59 and 60), which act wedge fashion (using the King Post as abutment), bringing up the strap and tie-beam. The upper ends of the principal rafters are square shouldered on to, and stub tenoned into, the enlarged head on the King Post and iron straps, shaped as shown on sketches placed on both sides and bolted through, serve to hold the whole together.

466.—The struts which are in compression are shouldered on to and stub tenoned into the principal rafters and the enlarged base of the King Post.

467.—The various other parts, such as ridges, common rafters, &c., shown in the sketches of the trusses, will be dealt with under separate headings later on.

468. Queen Post Truss.—The lower of the two frames shown by Fig. 59 is known as the Queen Post Truss, which is suitable for spans over 30 feet and up to 45 feet. It differs from the King Post Truss inasmuch as it has *two* posts supporting

the tie-beam. These posts are called Queen Posts. In addition to the difference

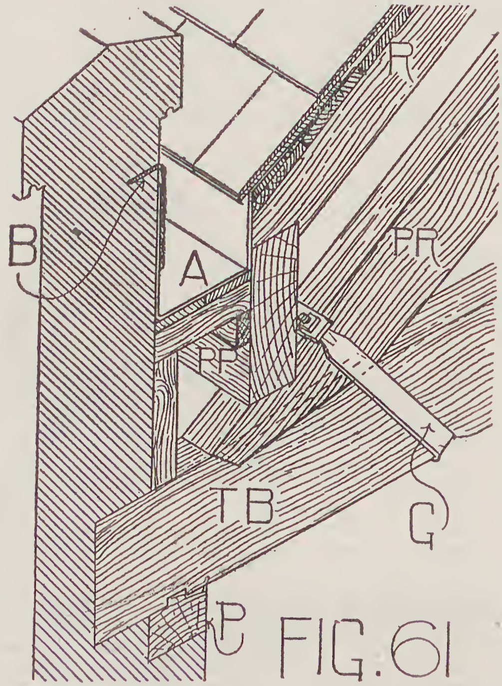


FIG. 61

in the number of posts, there are also two additional members called :—

(1) *A Straining Beam*, marked S.B., Fig. 59, which stretches between heads; and (2) *a straining sill* marked S.S. on Fig. 59 between feet of posts

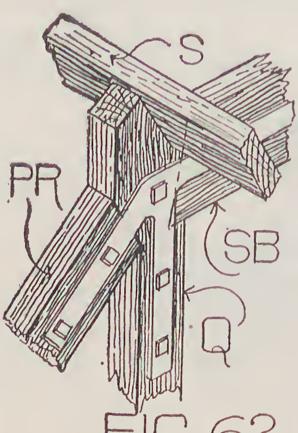


FIG. 62

469.—An enlarged view of the head of the Queen Post is given by Fig 62, in which the joints, with it. of the principal rafter (P.R.), the straining beam (S.T.), and the straps are also shown. The other joints are the same as those of the King Post frame described in the last article

470. Other Forms of Timber Truss.—When the span exceeds 45 feet two additional posts, called *Princess Posts*, are put, one between each Queen Post and wall. This form does up to 60 feet of span. Sometimes for spans of about 30 feet the King Post is retained in addition to Queen Posts.

471.—For large spans the arrangement of the various timbers becomes a very complicated matter, to go into which would be impossible unless plenty of space were available. and, indeed, it is hardly necessary. for the use of iron is becoming general for roofs of truss construction where it is only a matter of getting a covering for the

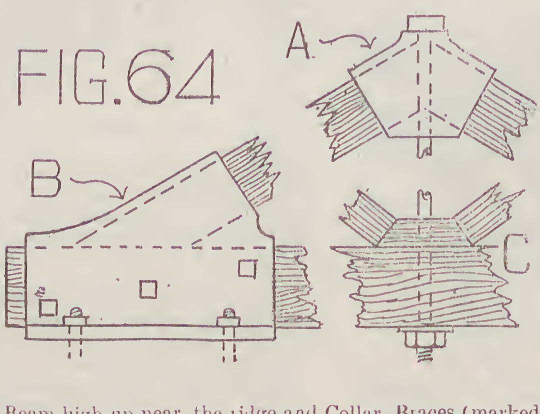
building, as for factories or where the roof construction is hidden by ceilings, as in the case of large dwelling houses and public buildings. It is, however, impossible to avoid noticing the kinds of truss used in Gothic work, for in this style of architecture the interior of the roof is left exposed to the eye, and the construction is planned to be ornamental as well as stable.

472. SOME EXAMPLES OF GOTHIC TRUSSES.—The sketches A, B and C, Fig. 63, illustrate, in skeleton form, three different kinds of braced frames in use in Gothic

FIG. 63

opened timbered roofs, and, though by no means covering the whole of the kinds, they may be taken as representative of the style of construction. The example A is a cambered and braced tie-beam truss with posts spaced at intervals on each side of the centre, the spaces between the posts being filled in with cut panels. The tie-beam would be cut with the upward bend or " Camber" out of a solid piece of timber. The sketch B, Fig. 63, shows a Collar braced Truss. In this case the collar beam is very high, and the stiffening of the truss is accomplished by the collar braces (marked D) which extend from under the Collar Beam and go down each principal rafter and down the walls for some distance. What is called a " Hammer Beam " truss is shown by C, Fig. 63. This kind, like the last described,

FIG. 64



has a Collar Beam high up near the ridge and Collar Braces (marked E), but the latter, instead of going down the walls, are stopped on to short projecting beams called *hammer beams* (marked F), which in their turn are supported by wall

braces (marked H) going from under them and down the wall. The collar braces are also secured at their lower portions against struts which extend vertically from the Hammer beams to the principal rafters. The jointing of the various together parts of these trusses is done in much the same manner as described for the King Post Truss in Arts. 463, 464 and 465 ante. It is, however, to be pointed out that these trusses (A. B and C, Fig. 63) are weak and entirely unsuitable for large spans, and even in small spans the walls must be thick and well buttressed to resist the thrust.

473. **Trusses of Iron and Timber Combined.**—Fig. 64 shows examples of the use of iron in conjunction with timber in what is called a *King Bolt Truss*. A is a cast-iron head or cap piece shaped to receive the upper ends of the principal rafters and drilled to take the head of a wrought-iron or steel King Bolt. B shows a cast-iron shoe fitted on and bolted to the end of a tie-beam, and formed to also receive the lower end of a principal rafter—the lower part of the casting being shaped as a seat for resting on, and bolting to stone template in the wall. In both cap and shoe pieces the thickness of metal should be enough to prevent rupture C shows the lower end of the King Bolt passing through the tie-beam, and also the ends of the struts stopped on to an abutment block through which the King Bolt also passes and keeps in position.

474. **It will be seen** that the necessity of depending on shoulder and tenon joints for the stability of the frame is removed by the employment of metal for the connections, as illustrated above, and the King Bolt is a great improvement on the timber King Post. The use of iron and steel in connection with timber on the principal as sketched out above may be extended with advantage to roofs for very large spans; a good style of construction being King, Queen, and Princess Bolts, with timber principal rafters, tie beams, and struts.

475. **Spacing Apart of Trusses and Sizes of Timbers.**—Trusses are usually spaced about 10 feet apart, being secured at the bearings on the wall to wall plates as shown at P, Fig. 61, or on to stone templates as marked at C, Fig. 59. When setting the trusses in position the greatest care should be taken to have them perfectly upright. The cross sections of timbers of trusses suitable for different spans, from to 20 to 60 feet, are given in the Table XXII. As noted on

TABLE XXII.*

Showing Cross Sections of Timbers of Trusses for Various Spans.
Pitch of Roofs 27°. Trusses Spaced 10 feet apart.

	SPAN. in feet.	TIE BEAM. in. x in.	KING POST. in x in.	QUEEN POSTS. in. x in.	PRINCESS POSTS. in. x in.	PRINCIPAL RAFTERS. in x in.	STRAINING BEAM. in. x in.	STRUTS in. x in.
KING POST TRUSSES.	20	9½ x 4	4 x 3	—	—	4 x 4	—	3½ x 2
	22	9½ x 5	5 x 3	—	—	5 x 3½	—	3¾ x 2½
	24	10½ x 5	5 x 3½	—	—	5 x 4	—	4 x 2
	26	11¼ x 5	5 x 4	—	—	5 x 4¼	—	4¼ x 2½
	28	11½ x 6	6 x 4	—	—	6 x 3½	—	4½ x 2¾
	30	12 x 6	6 x 4½	—	—	6 x 4	—	4¾ x 3
QUEEN POST TRUSSES.	32	10 x 4½	—	4½ x 4	—	4½ x 6¾	6¾ x 4½	3¾ x 2¼
	34	10 x 5	—	5 x 3½	—	5 x 6½	6¾ x 5	4 x 2¼
	36	10½ x 5	—	5 x 4	—	5 x 6¾	7 x 5	4¼ x 2½
	38	10 x 6	—	6 x 3¾	—	6 x 6	7½ x 6	4½ x 2½
	40	11 x 6	—	6 x 4	—	6 x 6½	8 x 6	4½ x 2½
	42	11½ x 6	—	6 x 4½	—	6 x 6¾	8¼ x 6	4½ x 2¾
	44	12 x 6	—	6 x 5	—	6 x 7	8½ x 6	4½ x 3
	46	12½ x 6	—	6 x 5½	—	6 x 7¼	9 x 6	4¾ x 3
QUEEN AND PRINCESS POST TRUSSES.	48	11½ x 6	—	6 x 5¾	6 x 2¼	6 x 8	8¼ x 6	4½ x 2¾
	50	12 x 6	—	6 x 6¼	6 x 2½	6 x 8½	8½ x 6	4½ x 2¾
	52	12 x 6½	—	6 x 6¾	6 x 2¾	6 x 8¾	8¾ x 6	4¾ x 2¾
	54	12 x 7	—	7 x 6¼	7 x 2¼	7 x 7¾	9 x 6	4¾ x 2¾
	56	12 x 8	—	7 x 6¾	7 x 2½	7 x 8	9¼ x 6	5 x 2¾
	58	12 x 8½	—	7 x 7¼	7 x 2¾	7 x 8½	9½ x 7	5 x 2¾
	60	12 x 9	—	7½ x 7	7 x 3	7½ x 8	10 x 7	5 x 3

*Tredgold.

the table, the sizes are by Tredgold, whose calculations, it is generally admitted, were on the safe side. Trusses made with Oregon or Baltic pine timbers, of the

cross sections given in the table, would carry roof coverings of Countess Slates or Pine boarding, and also ceiling joists and ceilings; for such a light covering as corrugated iron, which is put on without boarding, the timbers may be much lighter. The stresses in the various members of any kind of roof truss may be determined graphically as shown in Art. 17 *ante*, and the cross sections proportioned accordingly. The sizes of Purlins, common rafters, etc., are given later on, in special articles dealing with these parts of roofs. It may be mentioned that the tie-Beam, Principal rafters, and posts, should, if possible, be made of the same thickness so as to bring their faces to the same plane.

476. **Pitch of roofs.**—Table XXIII. gives minimum pitch for different kinds of covering.

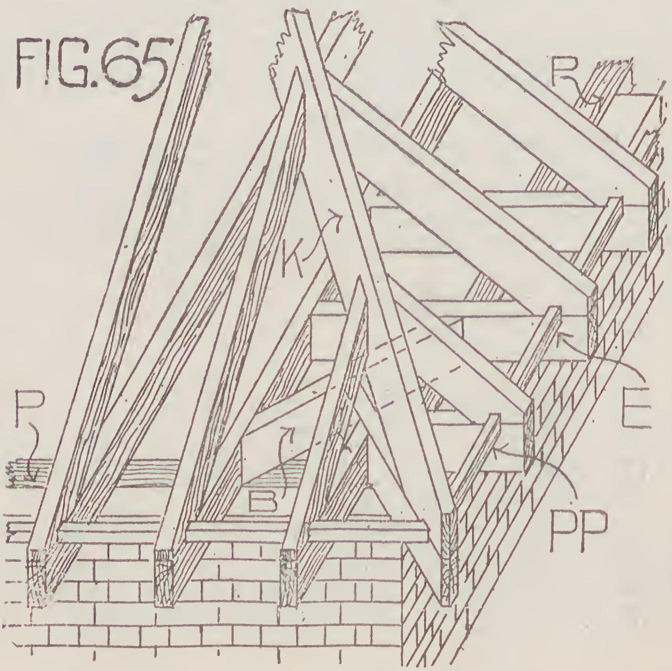
TABLE XXIII.

Showing Angle of Inclination (or "Pitch") of Roof Surfaces for Various Kinds of Covering.

Kind of Covering.	Minimum Angle of Inclination in Degrees.
Copper	$3\frac{1}{2}$
Lead.	
Zinc.	4
Slates (Queens).	22
,, (other kinds).	$26\frac{1}{2}$
Felt (asphalted).	$3\frac{1}{2}$
Corrugated Gal. Iron.	11
Tiles.	from 30 to 45.
Thatch.	45

477.—**Wall Plates** are the pieces of timber laid horizontally on the walls to receive ends of rafters in lean-to (see Fig. 57), single span (see W, Fig. 58) and collar beam (see Z, Fig. 58) construction; or the ends of ceiling joists in roofs of

FIG. 65



close couple construction (see Y, Fig. 58); or the ends of trusses (see Fig. 59). Wall plates are indicated by P, in Figs. 57, 58, 59, 61 and 65. Excepting in the

case of roofs of truss construction the wall plates are, as a rule, made 4in. x 3in. in cross section, this size serving to take up the space of a course of bricks. It will be seen by reference to the sketches that in most cases the wall plate is kept on the inner edge of the wall ; this position being the best. Where, however, it is desired to finish the eaves, as shown at right hand of Fig. 58, the plate may be put on the outside edge. The joint called halving (see Art. 411) is used for joining pieces of wall plate, either when to be continuous, or at right angles. Reference to Art. 427 *ante* will show that the term wall plate is also given to the timbers which receive ends of floor joists.

478.—CEILING JOISTS are the pieces of timber which are provided to carry the ceilings, and are put either—

(1) Under floor joists for lower ceilings, or

(2) Under rafters for upper ceilings.

479. CEILING JOISTS UNDER FLOORS.—Fig. 54 shows the relative positions of, and methods of securing ceiling joists (CC) to *binder* (B) in double and framed floors. This system of construction is, however, the exception rather than the rule ; the general method being to put the laths for the plaster, or the "firring" for metal or such other kinds of ceiling, or lining boards, directly on to the bottom edges of the floor joists, and there is much to be said in favour of this method, for the double framed floors are expensive and have disadvantages, as set out in Art. 434 ante ; although it is true that with ceiling joists separate from the floor joists the evil effects of vibration are avoided.

480. CEILING JOISTS UNDER ROOFS.—Sometimes, as, for instance, in lean-to roofs for rear buildings and verandahs, the ceiling is put on to the rafters ; and in collar beam roofs the ceiling is put part on collar beams and part on rafters. In these cases ceiling joists proper are not required. But in roofs of close couple (though in this case they serve also as Tie-beams) the ceiling carrying timbers are called ceiling joists (see Art. 459 *ante*). In roofs of truss construction ceiling joists must be specially provided, and they are either notched on to the Tie-beams, or spiked or cut on to fillets at side of Tie-beam in the same manner that they would be fixed to Binder, as shown by Fig. 54. Ceiling joists cut on to side of Tie-beam are shown marked CJ in Fig. 59.

481. TRIMMING OF CEILING JOISTS.—Ceiling joists should be trimmed for manholes, skylight openings and round flues. Also, in case of hipped roofs finished all round at eaves (as shown at left hand of Fig. 58), short trimmer ceiling joists are required to carry the eaves out and to receive the feet of rafters at ends of roof. Fig. 65 shows some of these trimmer joists going from the side of the last long joist out over the wall, and carrying the feet of the rafters. The trimming of ceiling joists should be in all cases as described in Art. 438 ante on trimming of floor joists.

482. BEARINGS AND SUPPORTS OF CEILING JOISTS.—Different methods of arranging the bearings of ceiling joists on walls, and under and against rafters are shown in Fig. 58. Ceiling joists should be further supported (excepting in the case of truss construction, where it is impracticable) by pieces of timber, called "*Hanging Pieces*," which extend from wall to wall on top of and at right angles to the length of the ceiling joists, and connected to each of the latter by pieces of 2in. x 2in. One hanging piece should be provided for joists with spans up to 12ft., and thereafter two up to spans of 18ft.; the cross sections of the pieces in all cases being sufficient to give stiffness to the ceiling.

483. TIMBER FOR, AND SPACING APART OF, CEILING JOISTS.—Oregon is about the best kind of timber for ceiling joists and is much used, but, hardwoods such as Tallow-wood, Blackbutt, White Mahogany, Spotted Gum, Red Mahogany, Grey Gum, etc., as well as Colonial Pine, are also greatly used. Ceiling joists are usually spaced 18 inches centre to centre to suit the laths which come to the market generally in lengths of four feet six inches.

484. SIZES OF CEILING JOISTS.—For pine joists, 2" thick with ½" of depth for every foot of span is a good size. A thickness of 1½" may be used in which case

the depth must be a little more than when 2″ thick. If hardwood is used it is best to keep the size about the same as for pine, for, although stronger timber as before pointed out it is difficult to get it seasoned. As regards the depth it is, however, well to point out that with the eaves finished as at left hand of Fig. 58 the maximum room span will decide the depth of all the others, for the depths at the eaves round the roof must be the same. If for the sake of economy it is worth while to have the depths different, the joists must be reduced to the same depth at the feet of the rafters to have the eaves right.

485. Ridge Piece and Ridge Roll.—The horizontal piece of timber to which the upper ends of the rafters are secured is called the *Ridge Piece.* It varies in thickness from 1″ in small, to 2″ or 2½″ in large roofs, the depth being made to suit the size of the rafters. Joints where necessary in the length are made with the scarf joint marked D, Fig. 48A. The piece of timber, partly rounded in cross section, shown on top of ridge piece at U in Figs. 58 and 60 is used to dress the lead ridge covering round, and is called the Ridge Roll.

486. Hip and Valley Rafters.—The external sloping edges formed by the intersections of surfaces of Hipped Roofs are called Hips. For an example see K, Fig. 56 To form the hips pieces of timber called *Hip Rafters* are put extending from the corner of the wall to the ridge (or to the upper point of the roof if there be no ridge), and on to them are cut and secured the upper ends of the short rafters. Fig. 65 illustrates a Hip Rafter (K) and small rafters (called *Jack Rafters*) together with ceiling joists, etc., of a roof with eaves to be finished as at left hand of Fig. 58. To prevent a thrust on the corner of the building the foot of the Hip rafter should be tenoned with a corner timber called a Dragon Piece, which bisects the angle of the corner of the building, and is held in place by being tenoned and pinned with a cross piece (B, Fig. 65) called an *angle brace*, which is in its turn tenoned into ceiling joists. Where there are no ceiling joists at the level of the plates as in a collar beam roof, the angle brace is secured by notching and spiking to the wall plate. Hips are surmounted by rolls, similar to those for ridges, where lead covering is to be used. The internal angles formed by intersections of roof surfaces are called *vallies.* (See D, Fig 56.) A valley is really the reverse of a hip, and the main points of construction are the same ; a rafter, called a valley rafter, about the same size in cross section as a hip rafter being put in to receive the upper ends of the short rafters, but the top of the valley rafter is kept down flush with the top edges of the rafters to allow the valley boarding to meet above it. (See Fig. 66, which shows a cross section of a valley ; A being the valley rafter ; C R the rafters ; and B the valley boarding. The Pole Plate is the piece of timber on to which the feet of the Common Rafters are cut. It is generally about 2″ x 2″ in cross section, and is, as a rule, in ordinary roofs let half its depth into the ceiling joists. A Pole Plate in ordinary roof construction is indicated by E, in Figs. 58 and 65. It will be seen by the latter sketch that the foot of the rafter comes directly over the ceiling joists so that the pole plate does not carry the rafters. In roofs of truss construction the pole plates are much larger in cross section, having to carry the feet of the common rafters as well as hold them in place. A pole plate in a truss roof is indicated by PP in Fig. 59, and by PP in Fig. 61. Hip and Valley Rafters and pole plates are made of pine ; Oregon being that usually used.

487. Purlins are the pieces of timber placed at intervals to support the common rafters. In roofs of truss construction the purlins bear on the principal rafters (having blocks below them at the point of bearing as shown at S Fig. 59) and span the distance between the trusses. See part of purlin marked S in portion of Queen Post Roof, Fig 62. In roofs of single span, collar beam, and couple-close construction the purlins are put with ends resting in the gables, if there be such, or, in the case of hip roofs, with their ends cut and spiked on to the hip rafters—the purlins in all cases being supported at intervals along the length by struts. The struts should bear *not* on to the ceiling joist, but, on to either cross walls or beams provided for the purpose and clear of the ceiling. A purlin as in an ordinary roof of couple-close construction is shown at S, Fig. 58. The Table XXIV. by Tredgold, which will suit the demands of ordinary practice, gives the safe scantlings of pine purlins for different spans and various distances apart in roofs covered with

slate. Joints where necessary in the length of purlins are made with the halving joint (see H, Fig. 48A), the joint, of course, always being over the point of support.

TABLE XXIV*

Showing Cross Sections of Pine Purlins.

Span in feet.	DISTANCE APART. 6 feet.	7 feet.	8 feet.	9 feet.
6	6" x 3½"	6¼" x 3¾"	6½" x 4"	6¾" x 4¼"
7	6¾ x 4	7 x 4¼	7¼ x 4½	7½ x 4½
8	7½ x 4½	7¾ x 4¾	8 x 4¾	8¼ x 5
9	8¼ x 5	8½ x 5¼	8¾ x 5¼	9 x 5½
10	8¾ x 5¼	9¼ x 5½	9½ x 5¾	9¾ x 5¾
11	9½ x 5¾	9¾ x 5¾	10¼ x 6	10½ x 6¼
12	10 x 6	10½ x 6¼	10¾ x 6½	11¼ x 6¾
13	10¾ x 6½	11¼ x 6¾	11½ x 7	12 x 7¼
14	11¼ x 6¾	11¾ x 7	12¼ x 7½	12¼ x 7½

*Tredgold.

488. COMMON RAFTERS.—These are the timbers, supported at their feet on to the pole plate and at their heads against the ridge piece, which carry the boarding or battens and slate or other roof covering material. The methods of cutting feet on to pole plates and heads on to the ridges are shown in Figs. 57, 58, 59, 60, 61, and 65. See also *Art.* on *Eaves* for further information as to finish at feet in certain cases.

489. Common rafters are spaced generally 18 inches centre to centre for slate or tile covering, but, for Corrugated galvanised iron they are, as a rule, put 3 feet centre to centre. The Table XXV. gives scantlings of common pine (such as Oregon) rafters for various lengths of span—the length of span being the distance between points of support such as pole plates, purlins, and ridges. In some cases of truss construction where a galvanised iron covering is used the common rafters are omitted, and the iron is put directly on to the purlins, which are in such cases spaced not more than about 3 feet apart. Rafters should be trimmed in the same manner as joists (see Art. 438 ante) round chimney stacks, openings for skylights, etc.

TABLE XXV.

Showing cross sections of pine common rafters for different spans. To be spaced 18 inches centre to centre.

Distance between points of support in feet.	Cross section in inches.
4	3 x 2
6	4 x 2
8	5 x 2
10	6 x 2

490. BOARDING, BATTENS, ETC.—The roof covering material is secured either to (1) Purlins, (2) Battens, or (3) Boarding. When secured to the purlins the common rafters are of course omitted. Battens are strips of timber (usually pine) ranging, according to weight of covering material from 1½in. x 1in. to 3in. x 1in. in cross section. They should be spaced apart to suit the tiles, slate, or iron covering, and well nailed to the rafters. Battens (one is marked D) are shown in Fig. 58. The lowest batten should be thicker than the rest, so as to give the bottoms of the slates or tiles a slight upward cast at the eaves. In better kinds of construction pine *boarding*, about 1in. thick, is nailed on to the rafters, as shown at B, Fig. 60, to receive the covering. In the example Fig. 60 the boarding is shown as parallel to the ridge, but a better way is to have it diagonally, for it then acts as bracing for the roof. In Gothic roofs, where the underside of the boarding is exposed, it is usual to have the longitudinal joints tongued and grooved, and the edges beaded. When boarding is used a narrow strip, called a *tilting fillet* (see Fig. 61), is put at the lowest edge to achieve the same result as the thick batten mentioned above.

491. **Roof Gutters.**—The making of gutters in connection with roofs is done partly by the carpenter and partly by the plumber. The former does the preparatory timber work, and the latter the finishing metal work. Unless the timber work is done so as to enable the plumber to put the metal in properly the gutter will not be a success. It will therefore be clear that the carpenter must have knowledge of the plumbers' work, which is to depend on his. For this reason the following, though mainly descriptive of the timber work of gutters, necessarily deals to some extent with the plumbers work. Roof gutters are made at the following places :—

(a) At horizontal lines of intersection of roofs with walls (see A, Fig. 61, and Q, Fig. 66.

(b) Between roof surfaces such as those of a V roof (see Z, Fig. 66.

(c) Behind upper faces of chimneys (see Q, Fig. 66. and at the upper edges of skylights, see Fig, 69).

492. Gutters at horizontal lines of intersection of roofs with walls are made either as shown at A, Fig. 61, which illustrates what is called a box gutter, or as shown at Q, Fig. 66, which is a sketch section of a gutter with one side sloping up with the

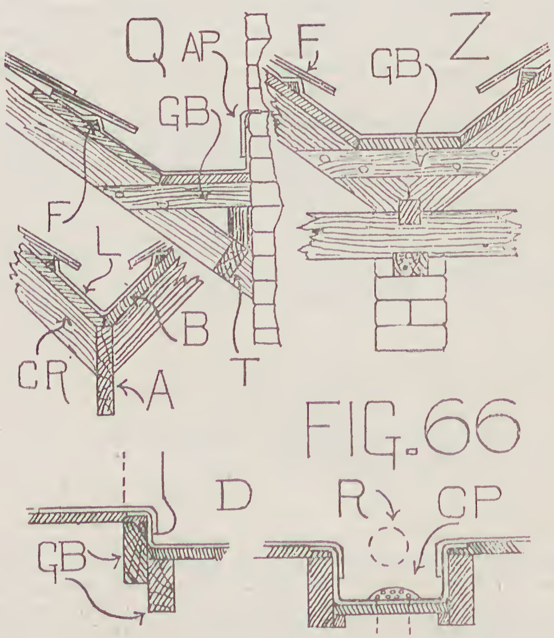


FIG. 66

pitch of the roof. Both of these kinds are used for behind parapets or where a wall extends up beyond the eaves. The box gutter A, Fig. 61, is formed with bottom of pine boards about 1in. thick, which rest on, and are nailed to, pieces of 3" x 2" called gutter bearers. The latter are spaced about 18 inches centre to centre, and rest at one side on a fillet secured to the pole plate and at the other on to small studs from the tie beams, and into the wall in the intervals between the trusses. The side of the gutter nearest the roof is formed partly by the pole plate and partly by pieces cut in on top of pole plate and between the rafters Box gutters are generally used in roofs of truss construction, and should be not less than 12 inches wide,

493. The gutter shown at Q, Fig. 66, has the bottom also formed of boards resting on gutter bearers, but the latter are secured to sides of common rafters at the inner ends. The sloping sides should be of the same thickness as the battens or boarding used on the roof. The gutter Z, Fig. 66, is an example of style generally adopted for V roofs, though in some cases a box gutter between two pole plates is used. The style of construction shown at Q, Fig. 66, is that used for behind chimneys, which, like that at E in the Hip roof, Fig. 56, are not at the upper edge of roof. In all these gutters, excepting those behind the chimneys and in other cases where the length is very short, what are called expansion joints or "*drips*" have to be made where the pieces of metal meet. When lead is used the drips should be not more than 12 feet apart; distances apart to suit the width of a sheet of lead are best. When gal. iron is the lining material the drips should be about 23ft. apart; this distance will allow of lengths of 3 sheets of gal. iron rivetted together between the expansion joints. The method of forming a drip is shown at D, Fig. 66. The sketch is a section taken in the direction of the length of the gutter. At the drip the gutter bottom is dropped, if possible, 3 inches, but not less than 1½″, the gutter bearers G B being arranged one lower than the other, as shown, to allow of the drop, and the edge of the upper bottom is rebated to receive the turn-over of the under lead. The sketch shows drip for a lead gutter; but, for gal. iron—which, by-the-way, is very much used—the preparation is much the same, the difference in the joints being more in the plumbers than in the carpenters work. If the lining is to be of lead the falls in the lengths between the drips should be not less than one inch, but, for gal. iron, the fall should be much greater as the iron does not lay so flat. Tilting fillets (marked F in Fig. 66) over which the inner upper edge of gutter lining, or apron flashing if there be such, should be turned, must be provided in all cases. At the lowest levels of gutters, "*wells*," or "*cess pools*," are formed, out of which the water is taken by a pipe leading to the down-pipe head outside. These cesspools are usually square in plan and from 6 to 9 inches deep. A section of a cesspool is shown at C P, Fig. 66. As will be seen, the cross sides are formed with extra deep gutter bearers—the bottom being formed of boarding, resting on fillets at sides of bearers. The transverse upper edges being formed just as drips.

494. **Eaves**, examples of which are shown at H H H, Fig. 56, are the lower overhanging edges of roofs. The methods of forming them may be put under two heads, though in matters of detail there is much variety :—

(a) Eaves with ends of rafters exposed.

(b) ,, ,, ,, boxed in.

495 (a) Eaves With Ends of Rafters Exposed.—The case of a common roof with eaves of this kind is shown by Fig. 57, in which the rafters are extended for some distance out past the face of wall, and a board (B) called a ***fascia board*** nailed along their lower ends. When a better finish is required the ends of rafters may be planed and also curved, and boarding, with lower faces dressed, put on top as shown in Fig. 58. In this case a second fascia is put along top of wall to cover wall plate and spaces between the rafters. Sometimes the ends of rafters are left rough and the boarding put underneath. The ends of rafters in truss roofs may be finished as above, see D D, Fig. 59.

496 (b) Boxed Eaves.—An example of a boxed eave is shown at left hand side of Fig. 58. In this case the ceiling joists are extended for some distance (see also Fig. 65) past the face of the wall, and boarding, called ***soffitt boarding*** (see G, Fig. 58), generally about one inch thick with under face planed, is nailed under them; the fascia (B) being also nailed to their ends. Boxed eaves in truss roofs are framed up at bottom of common rafters with 4″ x 2″ horizontal firring pieces as at A, Fig. 59. Boxed eaves are at times made very elaborate with mouldings on fascias, and brackets, or consoles, under the soffitt. Redwood makes an excellent timber for eaves work. Eaves when well finished go far to make a house look well, but for city architecture they are not safe on account of the easy passage, in the way of exposed timber, which they offer to fire from one building to another.

497. Dormer Windows.—Rooms in roofs are by no means uncommon, but, beyond the fact that the jois'ts must be made strong enough to take the floor weights there is nothing special in the timber work. The Partitions will be described under a special head later on. The windows called "*dormer windows*" which are put in to light these roofs rooms, or attics, are, however, deserving of a little attention now. The sketch Fig. 67 shows the skeleton construction of part of a dormer window. R R are the common rafters of the main roof. P is the wall plate of dormer, O the ridge, and V the valley rafter between the two roofs. The studs to form the sides of the projection of the dormer are shown (one is marked S) as halved, on to the common rafter. Fig. 68 shows a lower corner of a dormer in which A is tht corner stud and K the stile on to which a casement, opening outwards, would be hung. The stile K should be put in first with its lower end housed into the under sill Q, and the lead apron (L) turned round it and over the fillet (F) on under-sill, before the upper sill (H) is put in.

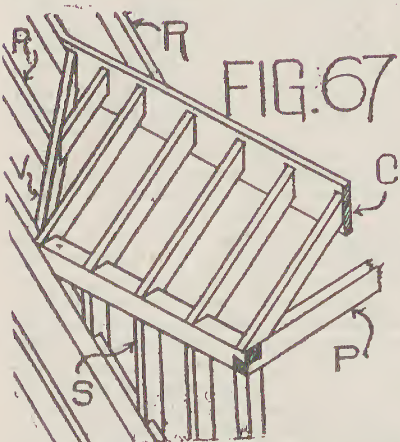


FIG. 67

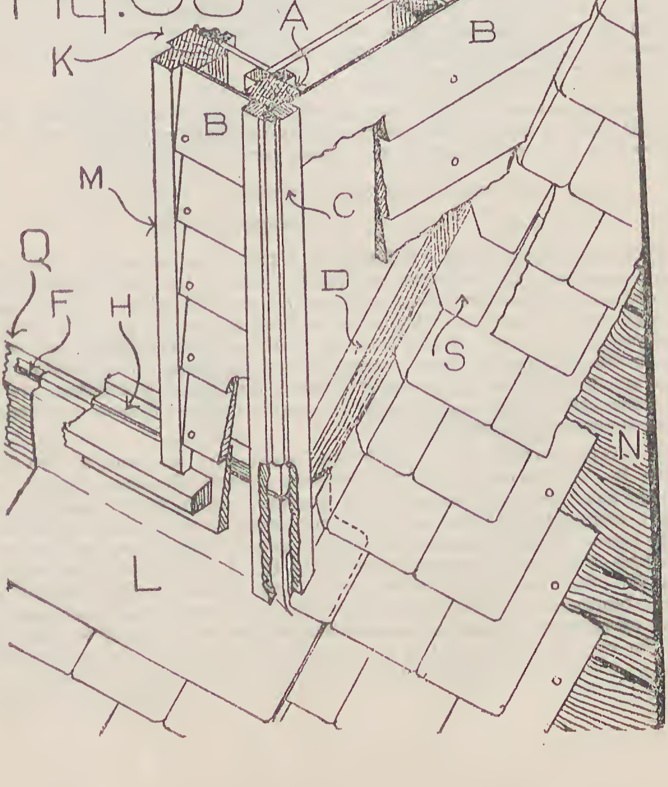
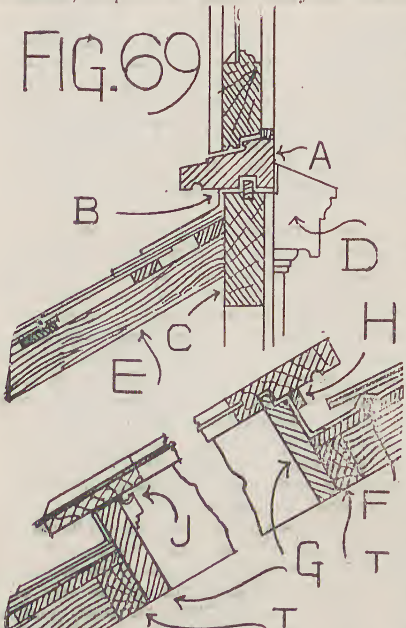


FIG. 68

In this (Fig. 68) sketch the sides and portion of front of dormer are shown as covered with weather boards, but slates, lead, zinc, muntz metal, tiles, and shingles are used at times for covering.

498. SKYLIGHTS.—A skylight is a window put in, and having the same, or nearly the same, slope as a roof. They are sometimes adopted instead of the dormer, described in last article, for attic rooms, and they are also much used to give light to stair halls and rooms where otherwise sufficient light is not obtainable. A section of a skylight is given in Fig. 69. T T are the trimmers to the rafters; G the lining board which goes round the opening, and on to which the sash is fastened. The sashes are made from 2″ to 3″ thick, the glass being let into grooves at top and two sides, but passing over bottom rail, which is of lesser thickness than the other parts of the sash. The lining should be tongued into the sash at top and sides as shown, and both the lead of upper gutter and aprons at the sides should pass over the tongues. A groove to stop the water running down should be put on the top under side of sash as illustrated in the sketch. A fillet (H) is sometimes put on at upper under edge as a further protection against water at the top joint. A fillet with a grooved top edge to take the inner edge of the lower lead apron should be put as at J, Fig. 69. This small gutter takes off to the sides the water of condensation, which collects at this under edge. In cases of important rooms and stair halls an under frame work, generally of an imposing design and filled with stained glass, is put under the skylight proper at the level of the ceiling so as to overcome the usually unsatisfactory appearance of the under side of the skylight.



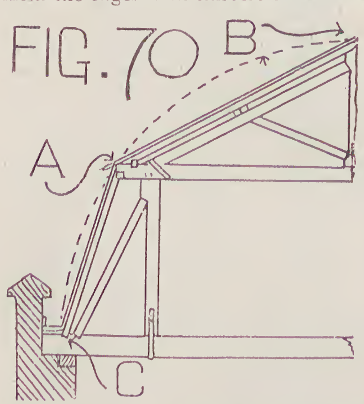
499. LANTERNS.—Top lights are sometimes made by elevating part of the roof at the ridge and putting in sashes, vertically, or slightly sloping, between the part so elevated and the lower portion. These lights are called *lanterns*. When building them the greatest care must be taken to have every possible guard against the inroads of the weather, for, like skylights, if not properly made they give the greatest trouble. The upper sketch, Fig. 69, gives section through the sill at one side of a lantern. C is the plate, or under sill, to which the tops of the common rafters E are cut and secured. A is the sill of the lantern, which should not be put into place until the upper part of the lead apron is taken over a fillet which projects from upper edge of plate C. The bottom of the sill A should be grooved to take this fillet with the lead over. The lead apron should, if possible, be taken right through and turned up at the back of the sill A. If the lantern is on a hip roof (in which case the sill will be returned at the ends), particular care should be taken that the fillet goes right to the angle and that the lead is taken out over it, and further, that the lead is not jointed just at the angle, but that it is in a single piece for at least 18 inches on each side of corner. The sill A should be grooved on under side near the front. The roofs of lanterns present no features much different from ordinary roof work. If the wind is to be feared the lantern may be secured by iron straps, extending from sill A to plate C. D is a moulded cornice to cover the joint of the two sills. Sometimes lantern construction is adopted to provide a covered look-out from the roof, in which cases floors are put in a suitable level to allow of sight from the windows.

500. FLATS.—It often happens that where yard room is not obtainable the roof is made flat so as to serve the purpose of a yard. At other times the space between two parallel ridges is bridged over with a horizontal surface to avoid a gutter in between, or to provide space for a room. Again, it is a common thing to have roofs of bay and oriel windows and other small areas finished with parapets and covered with flat roofs. The flats are made much on the same principle as a floor. If the space above is to be a yard the joists must be strong enough to stand the weight. If the horizontal space is only to serve as a roof it will be enough to have the joists strong enough to carry itself including covering material. The joists should be spaced 18 inches centre to centre, and the upper surface should be formed with stout boarding, well seasoned, and brought to a fair upper surface. The fall of the flat should be not less than 1 inch in 10 feet. In all cases the joists should be supported by bearers or purlins at frequent intervals. Where the lower edge of flat is behind a parapet, a box gutter as at P P, Fig. 61, should be provided. Where metal is used as a covering rolls must be fixed; see description of plumbers work later on as to spacing of rolls.

501. ROOF VENTILATORS.—These may be triangular, or other shaped, frames with louvres; the latter being inclined boards ranging in thickness from ½in. to 1in. and each covering the other to some extent as shown at C, Fig. 71. The vent frames are placed in a variety of ways Sometimes they are built in little gable like projections from the main roof, in which cases the construction is much after the style of that for dormer windows, shown in Fig. 67, the vent frame with louvre being put in the front. In cases, where the roof is hipped, the main ridge is extended past the point for distance and the side slopes of roof carried on also, thus forming triangular openings at ends which are filled with louvres. Again, a by no means uncommon way is to put a lantern at top of roof, but, instead of putting in the glazed sashes, louvres of glass are put in between the studs. Another way, where there are gables, is to put the ventilator frames in the brickwork. In all cases where put in projections from the roofs, the care described as being necessary for sills of dormers and lanterns should be taken.

502. BARGE BOARDS AND FINIALS.—In cases where the gables are not carried up with parapets it is usual to project the roof over the walls for some distance and finish the edges with timbers called *Barge Boards* Fig. 71 shows at A and B front and cross section respectively, of a Barge Board. The wall plate, purlins, and ridge are extended out past face of wall to carry one, two, or three common rafters as the demands of the projection may require. The barge boards, which vary in thickness from 1½ to 3 inches, are nailed on to the outermost rafters. At the head they are either mitred together or tenoned into a vertical piece called a *finial*. In the example shown in Fig. 71 the upper outer edge of board is moulded and the slates shown as projecting slightly beyond the moulding Barge boards are made in a variety of ways and in different styles of design ranging from the very plain to the most elaborate. The example in Fig. 71 is a plain board with mouldings near the upper edge only and fitted with a turned finial at the head In some cases the boards are cut and carved, producing curves of a flowing nature, and often enough resulting in effects very like wedding cake ornament. In other cases the boards are framed up with panels, and sometimes the whole is made to look like an ornamental truss with tie-beam struts etc

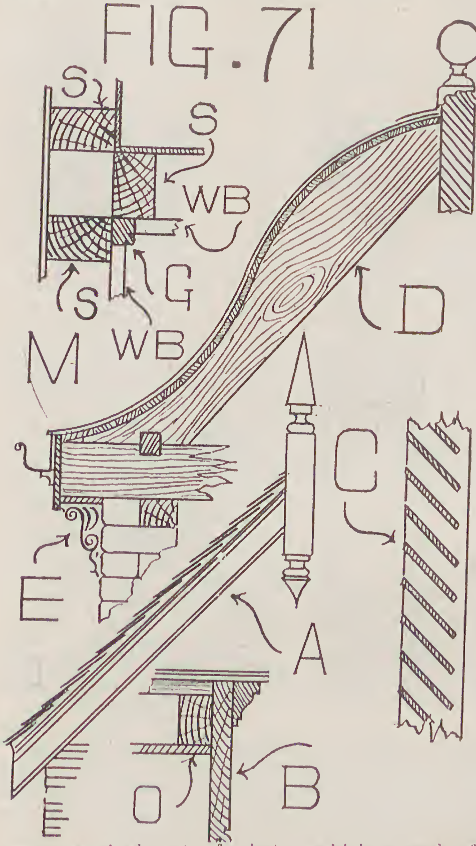
FIG. 70



503. MANSARD AND CURVED ROOFS.—A slight notice of these, to some extent uncommon roofs, is all that is possible on account of the limits of space Fig. 70 shows half of a truss for a MANSARD ROOF. To get the form proceed as follows:—Draw a line for top of tie beam. Mark on this the toes of common rafters (one is marked C in Fig. 70). Draw a semi-circle ex-

tending from toe of common rafter on one side to toe of common rafter on other side. Divide this semi-circle into 5 equal parts. The line from toe to first point of division on each side (A is the point in the half shown) gives the shape of lower part of roof. The line from first point of division on each side to top of semi-circle will give shape of top of roof. The top slope in sketch is from A to B.

FIG. 71



504.—The Mansard form of roof is very good where a story in the roof is needed. The truss is framed up on principles similar to those described for other trusses. The eaves may be finished in any of the ways shown in sketches. Figs. 58 and 59. The walls are generally carried up as parapets, as shown in Fig 70. Large roofs of curved form are now-a-days made almost without exception of iron, but, for roofs of ornamental form for towers, turrets, small pavilions, etc., may be built with economy, out of timber. These roofs are generally hipped, and range in plan from rectangular to all sorts of polygonal forms, and in vertical section from semi-circle to ogee. The way to build them is as follows:—The Hip rafters are cut to the curve required out of timber which may be from $1\frac{1}{2}''$ to $2''$ according to the length. If outside appearance only is of consequence, the under sides of rafters are left straight so as to preserve as much strength as possible (See D, Fig 71); but when the inner side of roof is also to show curved the curve must be cut on under side of each rafter as well. Intermediate rafters are cut with curves less flat (these curves should be properly projected by geometrical means), so that external edges of intermediate and hip rafters may, in each face, lie in the one plane of curvature. Some of the intermediate rafters will cut on to the hips as jack rafters, and the length of each will be part of curve of a full intermediate rafter. The sketch D, Fig. 71, shows an intermediate rafter for a small roof of ogee external form all with rafters coming to a point at the top. The rafters are generally covered with narrow boards on to which the metal or slate covering is fixed. The sketch is simply a diagram to illustrate the principle of construction, and the parts are not in proportion, for, unless in very small roofs, the rafters would be much larger.

STUD WALLS AND PARTITIONS.

505.—FRAMED OR STUD WALLS are constructed with uprights of light scantling spaced at equal distances apart, and mortised into plates at bottom and top, with an outside covering of weatherboards, and an inside lining of either boards or plaster. The external covering is sometimes of shingles, and even slates or tiles are on rare occasions used.

506. STUDS.—A sketch of a front view of part of skeleton of a stud wall is shown at A, Fig 72. The studs may be either of 4″ x 2″ pine or 4″ x 2½″ hardwood, and

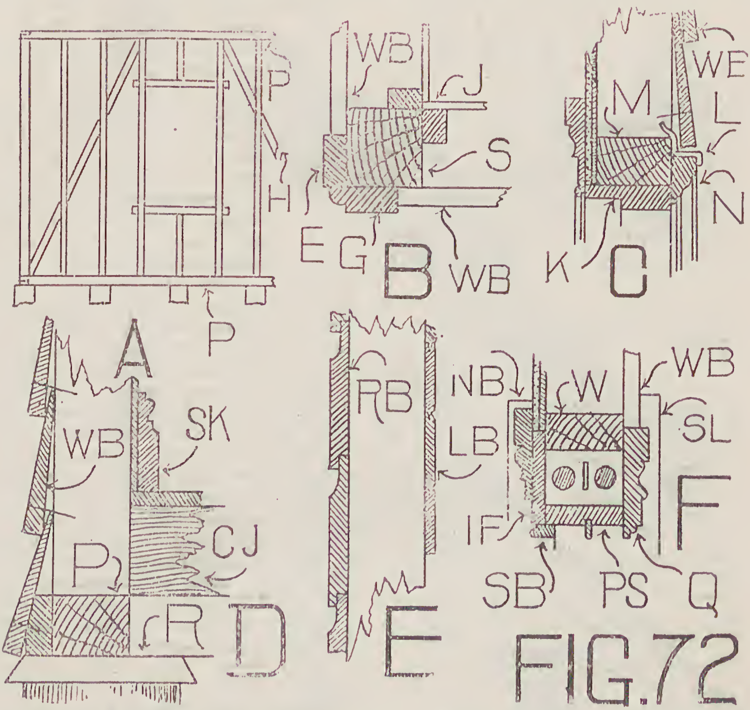


FIG. 72

should be spaced 18 inches centre to centre. Studs at corners should be square a cross section. Openings (See Fig. 72) for doors and windows are trimmed just is joists or rafters, but the tenon need only be a simple one. Wherever possible diagonal braces (H on sketch) should be put in. The braces may be 3″ x 1″ in cross section, and should be housed in flush with outer edges of studs.

507. PLATES—If supported on brick foundation walls the lower plates may be of 4″ x 3″, but if supported on piers, or piles, the cross section should be 5″ x 4″. Hardwood should always be used for lower plates. Brick piers to support plates should be not less than 9″ x 9″ cross section. If piles are used the diameter must be not less than 9 inches, and they should be coated with tar before being put in the ground. Capping pieces of gal iron should be put on tops of piles as shown at R, sketch D Fig. 72, before the plates are laid; but, if the foundation consists of brick walls or piers, a slate damp course must be put in. The *upper plates* are usually 4″ x 3″.

508.—WEATHERBOARDING is composed either of—

(1) Feather Edged Boards, or
(2) Rusticated Boards.

509. Feather edged boards are about 1 inch thick at lower edge and diminished to about ¼ of an inch at upper edge, the width being 7 inches. See sketches of cross sections W B at C and D, Fig 72. They are usually made out of hardwood (tallow wood and red mahogany being the best kinds for the purpose), but pine, both colonial and imported is also used. These boards should be fixed with a lap of 1½ inches and only one nail put from each board into each stud, as shown in the sketches, Fig. 72, so that shrinkage may take place without splitting. The lower external edges are shown sharp in the sketches, but there is no need to have them this way, for they may be either chamfer or beaded if desired. A tilting

piece should be nailed along plate to give the lowest board a bell cast as shown at D, Fig. 72.

510. RUSTICATED WEATHERBOARDS.—A sketch, showing cross sections R B of this kind of board is given at E, Fig. 72. As will be seen, the lower edge of each is rebated to receive the top edge of board next underneath. The boards are 9 inches wide, and 1 inch thick up to where commences the gradual reduction to form the top edge. Like the other boards they should have only one nail put into each stud.

511. Rusticated weatherboards are made out of Kauri pine or American redwood, the latter being much the best. *Heading joints of all kinds of weatherboards should be broken.* In the case of these boards the lowest cannot very well be tilted, as shown at D, Fig. 72, but to get the rain water clear the following arrangement is adopted :—A piece 6 inches deep with its top edge the same as those of rusticated boards and a bottom edge about 2½ inches thick with a drip groove is nailed with its bottom edge at the level of bottom of plate and its top edge fitted into the rebate of the lowest weatherboard.

512. METHOD OF FINISHING CORNERS OF STUD WALLS.—A horizontal section of an external corner of stud walling is shown at B, Fig. 72. S is the corner stud which, as before remarked, should be square. W B are the weatherboards overlapping the stud for a little distance and stopped against vertical pieces (E and G) called stops. As will be seen, one stop overlaps the other and is moulded so that an ovolo is formed at the angle. Fillets are generally nailed on inner faces of stud, as shown, to provide bearing and nail hold for laths or inside lining boards. An isometric sketch of finish of a weather board corner is given in Fig. 68, in which A is the corner stud and C one of the stops, B B being the weather boards. For the method of finishing internal corners see M, Fig. 71, in which S S S are the studs, W B the weatherboarding and G the stop against which the weatherboards are butted.

513 METHOD OF FINISHING HEADS OF OPENINGS IN STUD WALLS.—C, Fig. 72, is a vertical section of the head of a door opening ; M is the head which, as before noted, should be tenoned into adjacent studs as a trimmer ; K is the jamb lining head ; N the outside stop ; and W B the weatherboards. With a view to keeping out the weather a lead flashing should be put behind the weatherboard and against the head, and should extend out over, and down face of stop for a little, as shown at L. A window head would be finished in the same way as regards the lead flashing.

514.—THE WINDOW SILLS IN STUD WALLS to be properly fixed should be put in as shown at B, upper sketch, Fig. 69 ; that is to say, a lead apron should be put in over fillet on trimmer sill, and turned up a little at back of window sill. Care being taken that the apron is also turned up beneath ends of window sill and studs. As a rule, however, the lead apron is not put in, and indeed in the majority of cases the trimmer sill is left out altogether, the window sill being housed into studs. The latter way is very slipshod, and allows the ingress of the weather. The front of sill is (whatever the method of fixing) generally allowed to extend for some distance on to face of weatherboards. (See Fig. 68)

515. WINDOWS IN STUD WALLS.—A horizontal section of a box frame set in relation to stud W, and weatherboards W B, is shown at F, Fig. 72. As will be seen, the outer facing Q of box frame serves also as a stop for weatherboards and an outside architrave.

516.—SIDES OF OPENINGS IN STUD WALLS are finished much the same as the heads, the omission of the lead flashing being the main difference, but it will be remembered that the weatherboards at the sides abut, end on, to stops or outside architraves.

517. INSIDE LININGS OF STUD WALLS.—Stud walls are lined on the inside with either

(1) Laths and plaster, or
(2) Metal plates of ornamental pattern, or
(3) Narrow thin lining boards.

Of the first two kinds of lining the steel sheeting is far the best, for, not only is it fire resisting, but it is also not affected by shrinkage, as is plaster. The sheets are nailed to battens put on to suit. Lath and plaster work will be dealt with later on. The lining boards are generally ½ an inch thick and 4 inches wide with

tongued and grooved edges, and are worked so as to show either a bead or a V joint at meeting edges when fixed. Lining boards may, however, be obtained 6 inches wide, and both the latter and the 4 inch boards can be got of greater thickness than ½ if desired. L B at E, Fig. 72, shows sections of narrow lining boards. They are nailed with two nails to each stud, and heading joints should be broken.

518. STUD PARTITIONS.—Stud walls are used in both brick and timber buildings and in roofs as partition or dividing walls. For such purposes the studs, plates and bracing are similar to those described in preceding articles on external stud walls, the main difference being that the lining, whether lath and plaster, boards, or metal sheeting, is put on both sides. Stud walls and partitions should be kept at least 4½ inches, but if possible 9 inches, clear of fire places and flues.

BALCONIES AND VERANDAHS.

519. A BALCONY is a railed in platform projected from the face of a wall, and supported by cantilever brackets, or consoles. In some cases balconies are formed of stone or brick in cement corbelled out, but, only those built of timber are to be dealt with here. The sketch at A, Fig. 73, shows section of a typical case of balcony

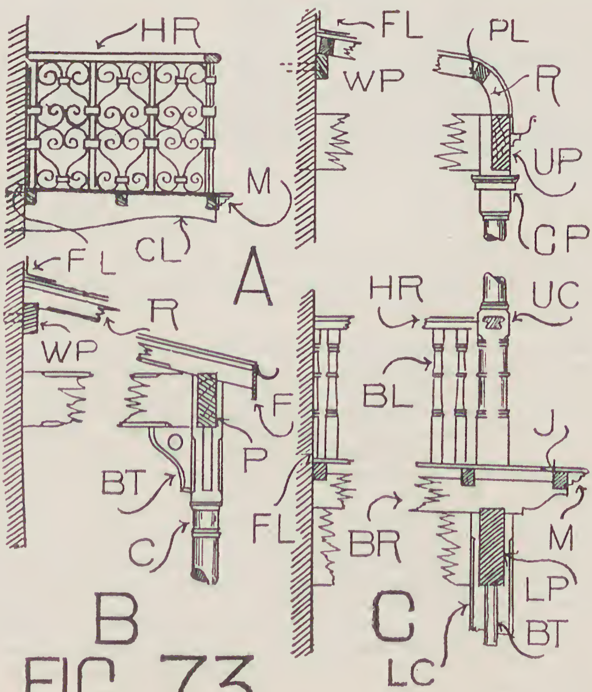


FIG. 73

construction. C L is one of the cantilevers which are either part of the floor joists extended out, or, are separate pieces put in through the wall and extended into the inner floor for some distance and well anchored with spikes to the floor joists. The cross sections of the cantilevers at face of wall is about 9″ x 3″ for a balcony, about 4 feet wide, and they are spaced about 36 inches centre to centre. The cantilevers are generally cut and shaped somewhat like the one in the sketch, though

of course, there is no rule to limit the design except that too much must not be cut away. Sometimes the cantilevers are put in rough, and the under surface of the balcony is formed with boarding nailed on to underside of the cantilevers. When this is done sham *cantilever brackets* or *consoles* of elaborate design are put underneath for the sake of appearance. The joists are pieces, of small cross section, (about 3" x 2" or 4" x 2") arranged parallel with face of wall and housed about ½ an inch into sides of cantilevers. The joists should be put in so that when the floor boards are on there will be a fall from wall to front edge of balcony to get the water off quickly. The joists being put in as shown in the sketch will provide for the floor boards being at right angles to face of wall. This is mentioned because sometimes the joists are omitted and the boards put on cantilevers and necessarily parallel to face of wall. This is a very bad style, for, the water will not run off across the longitudinal joints of the floor boards, even though a fall by sloping the top edges of the cantilevers be provided for. Cornice mouldings, as at M, Fig. 73, are put along the front side of outer joist, in case of construction as shown or (when the under surface is formed with boarding) along a fascia put on ends of cantilevers. In the style of construction shown, the edges of joists would be beaded or stop chamfered. The floor boarding would be tongued and grooved, and laid much the same as described in Art. 447 *ante*, but, being exposed on the under side, the under faces would also be dressed and the longitudinal edges beaded or V jointed ; and in laying, the tongues and shoulders of joints should be white leaded.

In the example shown the railing is of ornamental ironwork, which should be wrought rather than cast. The railing is, however, very often composed of pieces of timber about 2" x 2" in cross section, arranged to form some kind of pleasing pattern ; or, of balusters, as at B L, sketch C, Fig. 73. H R is the handrail, which (whether the under portion be of timber or of iron) is usually of timber.

The joint F L, sketch A Fig. 73) of floor with walls in all cases of timber floor should be flashed with 5lb. lead. Balconies are often roofed in, but this is done in the same way as hereafter described for verandahs, and so need not be touched on at this stage

520 A VERANDAH is a roofed space adjoining and at side, or sides, of a building to provide shade and protection from the weather and for use as a kind of out door sitting-room. The outer sides are generally left open Properly speaking, the verandah is only of one storey, but with houses of more than one storey it is very common to have the verandah also a double storied structure. The verandah is an essential in colonial domestic architecture on account of the climate which renders shade to the rooms necessary. It is, moreover, a feature which, if well designed and well constructed, adds much to the appearance of a house. The street verandah or awning used to cover the footpath in front of shops, and which is so common in colonial city and town architecture, is however, another matter altogether, for it is very difficult to get a good effect with a structure so foreign to the old world styles of architecture used for the street fronts. The trouble is intensified, too, by the very flimsy construction adopted, as a rule, for street verandahs. Shade for the shop fronts is, of course just as necessary as for rooms of private houses and until something better than the street verandah is evolved it will have to be built, but the construction should at least be good.

521. ONE STORY VERANDAHS.—The sketch at B, Fig. 73, shows section of a verandah roof of lean-to form. The rafters (R) are supported with upper ends on a wall plate (W.P.), and lower ends on a beam or plate (P). The wall plate is usually 4" x 2" in cross section, is beaded or stop chamfered on exposed edges, and is bolted to the wall with bolts ½ an inch in diameter, which are spaced about 36 inches apart. The outer beam or plate is generally about 9" x 3" in cross section, with beaded or stop chamfered lower edges and carried on posts which are spaced at intervals of about 10 feet. In cases where there are no end walls of brick or stone, the plate is returned at the ends (as shown by the sketch) ; the joists at the corners being made with mitre and dovetail. Joints where necessary in the lengths of plates are made over bearings with the scarf shown at D, Fig 48 A. Sometimes a small plate or frieze rail, as it is called, is put about 12 or 18 inches below the plate and its ends housed into the posts, the space between it and the upper plate being filled with turned balusters. Roofs of verandahs are exceedingly diversified in form, ranging from the simple lean-to to the ogee of pronounced

curve. The form known as "bull-nose" shown in upper part of sketch C, Fig. 73, is very much used. In these cases of curved form the rafters are cut as required out of timber about 2 inches thick, and the purlins (P L.) housed into their sides. In the very common work the rafters and battens or purlins are left out altogether, and the roof formed with corrugated galvanised iron in sheets (straight or curved as required) fastened at wall plate and outer plate; hip and valley rafters (if the roof is of a form to require such) only being put in. This is a style of construction which cannot be recommended, as it is very flimsy. The under surface of roof should be lined with boarding, put either on under or upper edges of rafters; if the latter way, the rafters must be planed and edges either beaded or stop chamfered. If tiles, which require fastening from under side, are used, the lining boards must be put on the under edges of rafters. Lining boards have been dealt with in art. 517 *ante*. The ground floors of verandahs are either of stone slabs, concrete with upper surface of cement rendering, or paving tiles, or timber If the latter the construction is the same as for other ground floors (see Art 427 *ante*), except that the joists must be parallel to wall so as to have floor boards at right angles to building, for the reason pointed out in the preceding article. The posts may be of iron or timber. If of the former, the wretchedly over-ornamented types of cast iron posts, or columns as they are called, which have become so common in Australian housebuilding should be avoided, and a sensible design more in keeping with the nature of the material, adopted. Timber is, however, under ordinary circumstances the most suitable for verandah posts for even when worked so as to be ornamental this material is the cheapest. Verandah posts of timber are made out of pieces ranging from 4″ x 4″ to 8″ x 8″ in cross section, about 5″ x 5″ being the size most generally used for verandahs of ordinary houses The top of post is generally cut out to allow of plate passing through it. In the plainest designs they are simply planed up and stop chamfered on the edges. The general practice is, however, to have them with portions of their length turned, circular, with plain cylindrical or vase shaped intervals, and mouldings; the lower, and top parts, and such portions as may receive abutments of handrails being left square. A better treatment, but of course more expensive, is to cut the mouldings and curves in on each side as shown in upper part of post in sketch Fig. 51. As far as possible all mouldings and other ornamentation should be cut into and not planted or fixed on to the post, so that the weather shall have as little opportunity as possible to cause decay. In this respect the verandah post is different to the story post described in Art. 425 *ante*, for the storey post generally carries a heavy floor or wall and there is consequently a reason for not reducing the cross section in any way. Moreover, the storey post is generally inside whereas the verandah post is not heavily weighted and is exposed to the weather. It must be mentioned however, that, the above reasons notwithstanding, cap mouldings planted on, as shown at C P. sketch C, Fig. 73 are very commonly used. Brackets made of timber about 2 inches thick and something like the form shown at B T. sketch B, Fig. 73, are sometimes put in the angle between upper part of post and plate. Timber verandah posts are illustrated at C. sketch B, and at L C and U C. sketch C in Fig. 73. In rare cases verandah roofs are supported by brick or stone piers, either extending up to the plates, or, carrying arches, and in most cases with the best possible results both constructively and aesthetically.

522. Two Storey Verandahs.—Structures of this kind are much used in houses of more than one storey. The construction is much the same as that described for the one storey verandah in the last Art.; the chief difference being the addition of a first floor, which is put at or about the level of the first floor of the house. This floor is composed of bearers, joists and flooring boards, and the whole is supported by a beam, or "*lower plate*," as it is called The lower plate is generally about 12″ x 3″ in cross section, and is worked and jointed in itself, and at posts and at angles in the same way as described for plates of one storey verandah. The bearers vary in cross sections (from 6″ x 3″ for 6ft. wide) according to the width of the verandah. They are spaced apart at distances ranging from 36 to 48 inches—one end bearing in wall and the other housed into top of plate—in each case they should fall towards the plate to allow for fall of flooring. As a rule the bearers are left exposed and are planed up, and the lower edges stop chamfered or beaded the ends being cut, as shown in the sketch, or covered with a

fascia and mouldings. Sometimes, however, they are left rough, and a ceiling of lining boards is put on to their lower edges. In the case of the latter, intervening ceiling joists are required, as the bearers would be spaced too far apart to carry boarding. In some cases panelling is put on as ceiling. The floor joists (J) and flooring would be as described in Art. on balcony floors, but the joists would not be less than 4" x 2" in cross section.

The two storey verandah is sometimes called a verandah and balcony, but this is hardly a correct term, for the upper part does not answer the definition of a balcony. The floor boarding would be of similar description and laid in the same way as described in Art. 519 *ante* for balcony floors. In the example sketch C. Fig. 73, a small cornice moulding (M) is shown put along outer face of outer joists and under outer ends of floor boards. A railing either of timber, or of iron work, is put round between the posts. In the example shown the railing is formed of 2" x 2" turned balusters (BL) spaced about 2 inches apart, with a timber moulded handrail (HR) on top. The roof would be the same as for a one storey verandah, all the parts being called by the same names as in Art. 521 *ante* except the plate which is known as an *upper plate* (U P), to distinguish it from the lower plate (L P).

523. **Timber** for balconies and verandahs must not only be able to stand exposure to the weather, but, also must be capable of being easily dressed, for as shown in the preceding articles, the timber work of these structures is nearly all planed and otherwise worked. The following is a list of timbers which are suitable for the various parts, but of course the questions of supply and cost govern this matter to a large extent, and for these reasons local timbers are often used, the fact notwithstanding that they are not the best for the purpose.

List of timbers suitable for parts of verandahs and balconies, the kinds being placed in order of suitability :—

Ground Floors : Any good hardwood.
Upper .. } Colonial Beech, Tallowwood, Oregon.
Bearers and Joists } Colonial Pine.
Flooring Boards : Colonial Beech, Tallowwood.
Posts : Colonial Beech, Tallowwood.
Plates : Oregon Pine, Colonial Pine.
Rafters : ,, ,, ,,
Mouldings, Facias, Hand-rail, Balusters, etc. } Colonial Beech, American Redwood, Oregon Pine, Baltic Pine, Colonial Pine.

N.B.—Hardwood may be used for plates and rafters, but the pine timbers are the best.

FENCING AND GATES.

524. **Fencing** may be divided into four kinds as follows :—

(1) (a) Split posts, rails and split palings.
    (b) ,, ,, ,, sawn ,,
(2) Sawn posts and rails, and sawn palings.
(3) Dressed posts and rails, and picket battens.
(4) Ornamental fencing.

525. **Split Post Rail and Paling Fence**.—This is a very rough, but, nevertheless, very durable and serviceable kind of fencing. The posts (about 9" x 3" in cross section corner posts being 9" in diameter) and the palings (about 1 inch thick and from 4 to 6 inches wide) are simply pieces split from the tree. The posts are sunk from 30 to 36 inches into the ground and spaced from 8 to 9 feet apart, and the rails, of which there are generally three tiers, are tenoned into them as shown at A, Fig. 74, which illustrates a fence of this kind. The palings, of which some are shown in position in the sketch, are nailed with two nails into each rail. The lower ends of the posts should be charred prior to being put in the ground. The (б) kind is the same as above with the exception that the palings, instead of being split, are sawn pieces ranging from 4 to 6 inches wide and about ¾ of an inch thick. This makes a better looking kind of fence. A safeguard against the palings being easily knocked off is provided in the form of galvanised iron-hoop bands nailed along on the outside of the palings at the levels of the rails and passing through the mortises in the posts, the width and guage of

the iron hoop being about $1\frac{1}{4}''$ and 16 respectively. Whether the palings be sawn or split, they should be fixed so that the tops make a continuous and perfectly level line. Sometimes where it is only a question of fencing in a paddock for cattle, or a field, the palings are omitted and the fence left to consist of posts and rails only. Again, in the case of the latter style of fence being adopted it is not an unusual thing to thread lines of No. 6 guage galvanised iron wire through the posts at levels midway been the rails, the wire being strained as tight as possible.

526. SAWN POST RAIL AND PALING FENCE.—In this kind the timber is all from the saw mill. The posts may be from 5in. x 3in. to 6in. x 4in. in cross section, corner ones being square; the sinking into the ground and the spacing

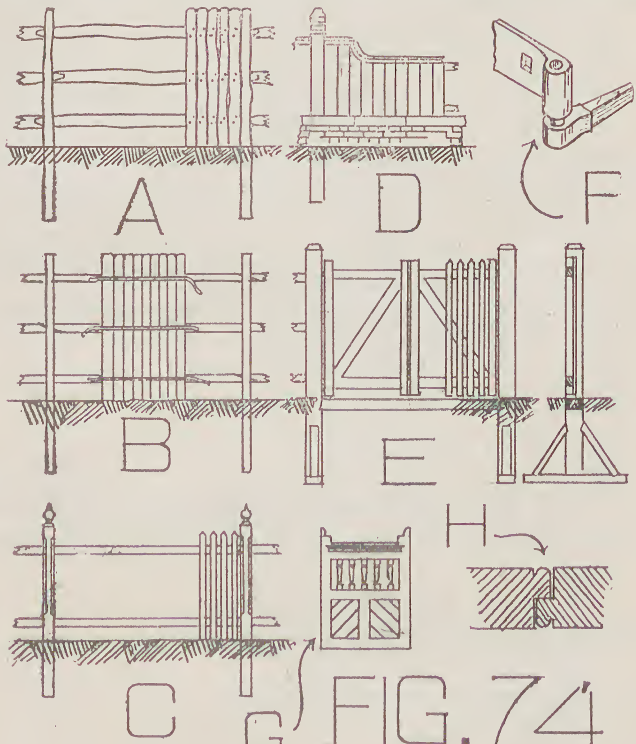


FIG. 74

part being about the same as for split fencing. The rails, of which there should be three tiers, are either 3in. x 2in. or 4in. x 2in. in cross section, and they should be neatly tenoned into the posts as shown at B, Fig. 74. In this kind it is advantageous to have the rails long enough to pass two spaces, and to arrange them so that the joints (which, of course, come at the mortice in the posts) will be broken, that is to say, two joints at one post, one joint at the next, two again at the next, and so on. It is necessary in this kind of fencing to tar the ends of the posts which are to go into the ground. The palings may be as described in last article *i.e.*, pieces 4 to 6 inches wide and about $\frac{3}{4}$in. thick, or they may be composed of feather-edged weatherboards, the latter kind being very suitable for fences enclosing spaces about houses, on account of the privacy which they secure, there being no crevices as in the case of sawn palings. The weatherboards should be fixed vertically with a lap of about $1\frac{1}{2}$in., and only one nail from each board into

each rail. It is difficult to get sawn palings thoroughly seasoned, consequently they shrink in the width after being put up, and ugly spaces or crevices occur. To guard against this it is a good plan to nail the palings temporarily (*i.e.*, secure them without driving the nail right in) in position and allow them to remain for some time to give them a chance to shrink after which they can be removed and re-fixed close together.

527. PICKET FENCE.—In this kind the posts are about 4″ x 4″ in cross section, planed on the surface, with the edges-top chamfered and the tops ornamented with turnery, or caps, sunk about 2ft. 6in. into the ground, and spaced about 8 or 9 feet apart. There are only two tiers of rails, the cross sections of which latter ranges from 3in x 2in to 4in. x 2in., or triangular 5½in. x 4in. x 4in, the latter being called "arris" rails. The rails are planed up on all faces and tenoned into the posts. In the case of an arris rail the large face is put for nailing to. The pickets are battens 3in x 1in in cross section, planed up on all faces finished with rounded or turned heads, and nailed to rails so as to be about 2in. apart. See sketch C., Fig. 74.

528. HEIGHTS OF FENCES are as follows :—

Split post and rail fence	5 feet.
Sawn post and rail fence	6 feet.
Picket fence	4½ feet.

529. TIMBER FOR FENCING —The various kind of hardwood noticed in Art. 329 to 354 *ante* make excellent material for posts and rails. The sawn saplings should, however, be of tallow wood or black butt. The weatherboards should be of tallow-wood, red mahogany, or blackbutt.

530. GATES.—An ordinary gate, for an opening about 7 feet wide, such as is used for a vehicle entrance in a fence, is shown at E. Fig. 74. As will be seen, it is composed of two frames, or leaves, each of which is composed of two vertical side pieces, two cross pieces, a diagonal brace, and a covering or sheeting of batten pickets. The vertical side pieces and the cross pieces are called stiles and rails respectively. The rails should be tenoned into the stiles and the joints white leaded, and secured with wedges and pins When the pickets are nailed on, their outer faces should be flush with outer faces of the stiles. To accomplish this, the rails and braces are made less, by as much as the thickness of the pickets, than the stiles. To obtain the greatest good from the braces they should be put in so as to go upwards from the end of lowest rail nearest to the post on which the leaf is hung. The two centre or meeting stiles should be rabated and beaded to fit each other as shown by cross section at H., Fig 74. Sometimes, instead of working the rebates and beads on the stiles, stop beads are nailed on so as to serve the same purpose. The sheeting or covering of the leaves may be 4in. x 1in. or 6in. x 1in. T and G and B (or V jointed) boards instead of the pickets shown in the sketch.

531. The posts to which the gates are hung should be stiffened at the ends in the ground by being tenoned into horizontal cross pieces, or *sole plates*, and braced with struts as shown in the sketch E, Fig. 74. The depth of the posts in the ground should not be less than 3 feet, and, like fence posts, this submerged part should in every case be well coated with tar. A piece, called a sill, should be put in at level of bottom of gates between the posts as shown by sketch. The best kind of hinge for suspending the leaves is that known as a "*hook and eye hinge*," illustrated at F, Fig. 74.

532. The following are the sizes generally adopted for the various parts of the gate shown at E, Fig. 74 :—Stiles, 4in. x 3in. ; rails, 4in. x 2in.; braces 4in. x 2in.; pickets, 3in. x 1in. ; posts, 8in. x 8in. ; sole plates, 8in. x 4in. ; struts, 4in. x 3in.; sill piece, 9in. x 6in.

533. Small gates in one leaf for openings about 3 feet wide are called "wicket gates." One is shown at G, Fig. 74. In this case the stiles and rails would be about 4in. x 4in. in cross section ; the lower panels being filled with 4in. x 1in. tongued and grooved beaded boarding placed diagonally and held in grooves ; the upper part being filled with 2in. x 2in. turned balusters housed at bottoms and tops into the rails ; and the top rail being surmounted by a moulded capping piece. As a rule, however, wicket gates are made just as one leaf of the double gate described in Art. 530 *ante*.

534. Timber for gates should be as follows :—Posts : Hardwood of good

quality such as ironbark, tallowwood, red or white mahogany, grey or red gum and turpentine. Leaves: Oregon pine, baltic pine, or where these cannot be got, good colonial pine.

535. The gate shown at E Fig. 74 is a very plain example and necessarily cannot be taken as representative of the field of variety in style open to the designer, but as far as the principles of construction are concerned the plain example is fairly typical of gate structures, for, the difference is mostly in the matter of ornamentation.

536. JOINERY WORK.—The timber work described in Arts. 425 to 535 in this chapter has been chiefly what comes in ordinary classification under the head of Carpentry; the exceptions (such as finishing of eaves, skylights, lanterns, ventilators, Barge boards, ornamental parts of verandahs and balconies, and gates) being cases of work which, strictly speaking, belong to joinery, but which have been dealt with on account of the advantage of describing, together, parts closely related. It is well nigh impossible to draw any distinct line of division between the two classes of work, because one trenches into the other to a great extent, and, as a matter of fact, they are both included in the one trade. As stated at the commencement of this chapter (see Art 407), Carpentry consists of the parts essential to stability, while the Joinery embraces the more delicate, though not necessarily more skilful, work of making and fixing doors, windows, stairs, and such fittings. So far, this is perfectly correct, but in a detailed description of the two classes it is not so easy to distinctly classify. To illustrate the difficulty, take the case of a roof, which is, as before stated, a work of Carpentry, but the workmanship required to finish some of its parts, such, for instance, as barge boards or skylights, is often of a kind which may be rightly held to belong to joinery. To simplify the description such parts have been noticed as occasion demanded during the description of the Carpentry work. Work, which, according to the usual definition, comes under the head of Joinery is dealt with in the remainder of this Chapter.

GENERAL IN REGARD TO JOINERY WORK.

537. FINISH OF JOINTS IN JOINERY WORK.—In all kinds of timber work the parts of the joints should be made to fit with accuracy, so as to ensure strength; but in Carpentry the joints need not be made with the extreme neatness of workmanship which is necessary for the sake of appearance, in Joinery. In the latter class of work the joints which are intended to remain tight up, should be made so that the junctions are perceptible only by the difference of grain of the pieces joined.

538. GLUE FOR FASTENING JOINTS.—Many of the joints in joinery work not exposed to the weather are fastened with glue. This substance is a gelatine obtained by boiling to a jelly the skins and hoofs of animals. The process of manufacture briefly described is as follows;—The materials are first placed in a lime pit, and after being well steeped are washed and placed on frames to dry, after which they are boiled down to the consistency of jelly. The jelly is then strained and allowed to stand for a time so that impurities not removed by the straining may settle to the bottom. The clarified portion is then boiled a second time, and further clarification is accomplished by settlement, and by the addition of chemicals. It is then run off into coolers about 6ft long, 1ft. wide, and 2ft. deep, in which it becomes a firm jelly. It is then cut up into square cakes, and sliced into thin pieces, which are placed on nets to dry. After some time the slices are removed to lofts, where the final degree of hardness is reached. The best kind of glue is hard and brittle, of a light amber colour and nearly transparent When placed in water it swells considerably; but should not dissolve; and should return to its original size when re-dried. The method of preparing glue for use is as follows:—The glue is broken up into small pieces and steeped, in as much water as will cover it, for about 12 hours. It is then melted in a proper glue-pot, care being taken that the outer vessel of the pot is filled with water so as to prevent the temperature in the inner one being raised above the boiling point of water, for, if the glue is burnt it becomes useless. The glue should be applied as hot as possible to the timber, and a minimum amount only should be used, as an excess reduces the strength of the fastening. Considerable attention should be paid to quality and preparation of the glue used in such framed work as doors, sashes, panelling, etc., for upon the glue fastening depends the firmness of the joints.

Glue may be made capable of resisting moisture, and, consequently, of use for joints exposed to the weather, or, to water, by putting a small quantity (about 1/50 of the quantity of the glue) of bichromate of potash in the water which is used for preparing.

539. FINISH OF SURFACES.—The exposed surfaces in joinery should be finished by being brought to a perfectly smooth state, and free from plane and other marks by the use of glass paper The latter is paper faced with pulverised glass, and is supplied in different degrees of coarseness, ranging from No. 0, the finest, to No. 3, the roughest

540. FRAMING is the term which in joinery is more particularly applied to constructions composed of vertical pieces and horizontal cross pieces with intervening spaces filled with boards. The outside vertical pieces, or "*stiles*," are always in one peice from bottom to top of frame, and are mortised to receive tenoned ends of cross pieces, or "*rails*," and the boards or "*panels*" are secured by being let into grooves made in the stiles and rails. Vertical pieces, other than those of outside

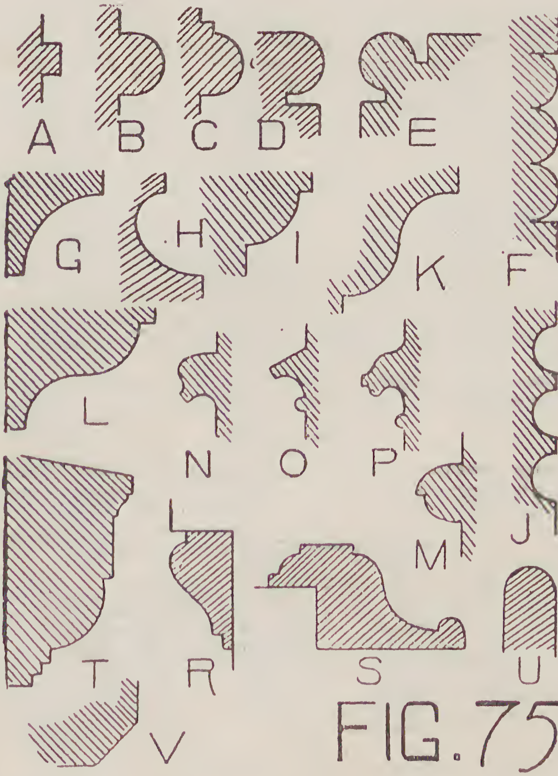


FIG. 75

edges of frame. are put in between and tenoned into the rails. Particularly dry timber must be used in framed work. but, even so, the scantling of the timber should not be too great, as the smaller the cross section of stiles and raits the less the liability to shrink and the better the work. The tenons are, for inside work, always secured with wedges and glue The panels should fit fairly tight, but, provision should be made for expansion and contraction, and they should not be fastened with nails or glue. Framing should always be put together loosely, and

allowed to stand for sometime before being permanently tightened and glued.

541. PLUGS.—Pieces of joinery work, such as linings, skirting boards, architraves, etc., are fixed to walls by nailing to plugs, which are pieces of cedar or Baltic pine, slightly wedge shaped, about ⅜" thick and about 2" wide, driven tightly into the joints of the brickwork or masonry at distances apart of not more than 18 inches. An example of a plug is shown at P in Fig 78. In some cases slips of cedar the thickness of the joints are put in as the wall is built ; this is done to avoid the chances of damage to the walling by the driving of the plugs In superior work *grounds* are fixed to serve as foundations for the linings, etc. *Grounds* are pieces of timber (usually Baltic pine) nailed to plugs and arranged so that their outer faces shall be flush with the finished face of the plaster, (See G L, sketch E, Fig 76.) The edges next the plaster are bevelled so as to form a key for the latter. Sometimes a groove is formed in the edge for the same purpose The pieces of timber for grounds are made the same thickness as the plaster work and of a width to suit the requirements, which, it may be mentioned rarely render necessary a greater width than 4 inches. Where very wide grounds are required they are framed up out of pieces about 3 inches wide. Both plugs and grounds are put in before the commencement of, and serve as guides for the finish of the plastering work. Consequently the greatest care has to be taken that the heads of the plugs and the faces of the grounds come up to the one vetical plane, and that the outer edges of the grounds are plumb.

542. FIRRING is the name given to the strips of wood put on to level up to a fair surface. An example of the use of this "firring," or "packing,' is the case of the forming of a ceiling with lining boards. It often happens in a work of this kind that the edges of some of the joists instead of being quite straight, are concave, and require to be packed up with strips of wood to the same plane as the straight ones, so that the surface of the ceiling shall be free from hollows.

543. CRADLING —When a girder, for instance, is to be covered with a casing of boards, or panelling, or with plaster work, rough framing consisting of pieces of timber 2in. x 2in. in cross section are built at intervals round its sides and bottom to carry the casing boards, or laths for plaster, as the case may be. This framework is called "*Cradling*, which may be briefly defined as a supporting framework for casings of girders or columns, plaster work of heavy cornices, and ceiling, coves, etc.

544. MOULDINGS are continuous straight (or curved) lines of projecting (or recessed) plane and curved surfaces used for decorative purposes in building work.

TABLE XXVI.

Giving names and particulars of mouldings shown in sketch, Fig. 75.

DISTINGUISHING LETTER IN SKETCH.	NAME, &c.
A	FILLET : Generally used with other members.
B	ASTRAGAL : Usually called a *bead*.
C	TORUS : Composed of bead and fillet.
D	QUIRK BEAD : Used for edges of tongued and grooved boards, etc.
E	DOUBLE QUIRK BEAD : Called a *returned bead*. Used for corners.
F	REEDING : A number of beads together.
G	CAVETTO : As a rule this is called a *Scotia*.
H	SCOTIA : This the proper form.
I	OVOLO, or quarter round.
J	FLUTING.
K	CYMA RECTA OR OGEE.
L	CYMA REVERSA, or reversed ogee.
M N O P	FORMS OF GOTHIC MOULDINGS.
R	SUNK MOULDING FOR PANELS.
S	BOLECTION MOULDING, ALSO FOR PANELS.
T	MOULDING suitable for transoms, capping, etc.
U	NOSING : Used for edges of stair treads, window boards, etc.
V	CHAMFER : Much used for edges of all kinds of timber work.

Each style of architecture has its own peculiar kinds of mouldings and the design of these parts is a very important branch of architectural study, and a subject

quite beyond the scope of these articles. But, as the common forms of mouldings are necessarily very often referred to, especially in the articles relating to joinery, it is hardly possible to avoid giving a few particulars, consequently some cross sections or "profiles" of the principal members of the classic mouldings, together with a few of Gothic and Modern style are given in Fig. 75. So as to be as brief as possible, the names and other particulars are given in table XXVI, page 142. Timber mouldings are generally run by machinery, but require to be finished with hard planes, and should be well sand-papered so as to bring the edges perfectly straight and the surfaces smooth.

DOOR OPENINGS.

545. The subject of door openings can be most conveniently dealt with under the following heads, viz. :—

(*a*) Frames, and the finish round them.
(*b*) Doors.

546. **(*a*)** Frames are either "*Solid*," or what are called "*Jamb Linings.*"

547. **Solid door frames** are used for external door openings, and are so called because the head and upright side pieces are of stout scantlings and do not require stiffening support, that is to say, they are stiff enough in themselves to form a

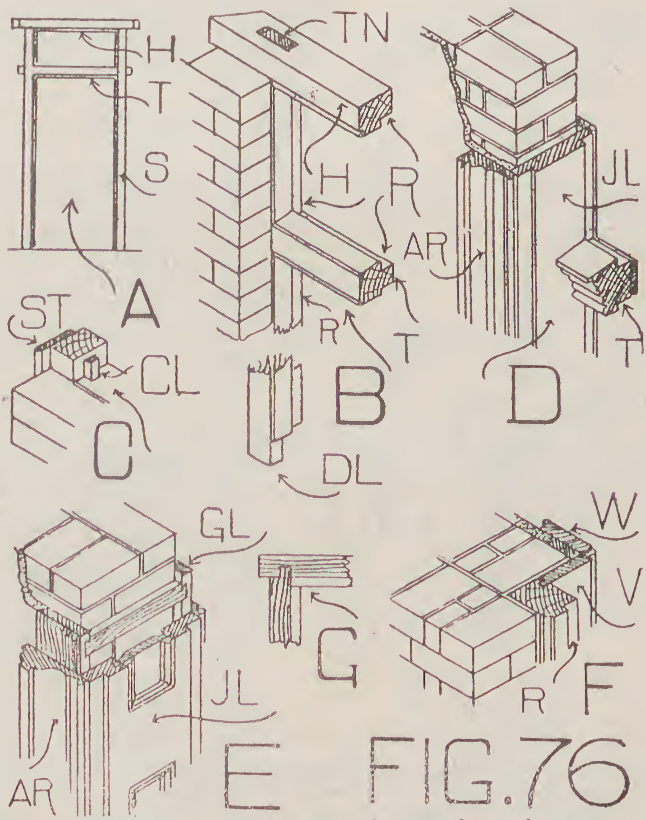


FIG. 76

frame which only requires support to keep in place. A front elevation of a solid frame is shown in sketch A. Fig. 76 The side pieces (S) are called "Stiles," and the top piece (H) the head. In the frame shown provision is made for a fanlight,

or sash, over the door, the cross piece (T) separating the door from the fanlight being called a "Transom."

548. The Sketches, B, C, and F, Fig. 76, give details connected with the construction and finish of solid door frames. The stiles are tenoned into the heads as shown at T.N., sketch B, Fig. 76, and the joints painted with white lead paint, wedged (as shown at H, Fig. 49), and well spiked. As shown by sketch B, Fig. 76, the ends of head pieces are allowed to extend for some distance past the stile so that the wedging of the tenons may be done. These extended portions are called "Horns." In cases where the door frames are flush with inside surfaces of walls (see sketches B and C), the ends of the horns are cut on the bevel with a

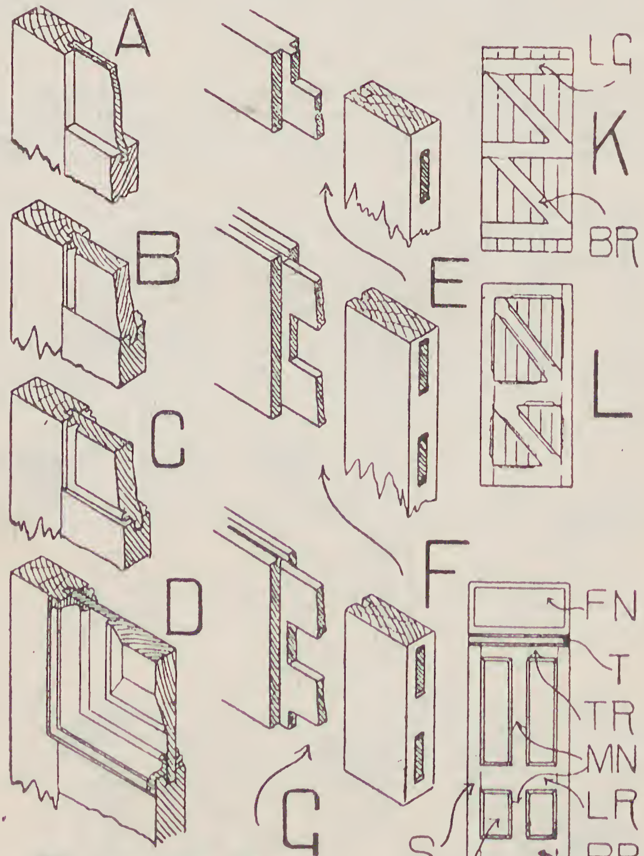


FIG. 77

view to providing, on the principle of the dove-tail, a good hold in the wall. The feet of the stiles are finished with a tenon (as at D.L.. sketch B, Fig. 76), which is let into a mortice cut in the stone door-step. An alternative method of fastening the feet of stiles into the step is to have a metal dowel passing from foot of stile into the step. (See dowel joint X, Fig. 49). In the sketches B and F, Fig. 76, the rebates R,R,R, into which the doors and fan-lights fit, are cut out of the timber

of the stiles, heads, and transoms. When this is done the outer edge of the frame, which projects a little out from the masonry or brickwork reveal, is beaded as at sketch B, or moulded as at sketch F. In some cases, however, the rebate is formed by planting on a "*stop piece*" of pine about ½" thick, beaded on outer edge and put so as to cover the joint of the frame and reveal, as at S P, sketch C, Fig. 76.

549. **TRANSOMS** —As before remarked, a transom is a cross piece put in between head of door and bottom of fanlight, when the latter is to be provided. Transoms are either plain beaded as at T, sketch B, or moulded on outer face, as at T, sketch D. As a rule, they are rebated for head of door and bottom of fanlight, as shown in the sketches. Sometimes, however, the rebate for the fanlight is omitted—the top being simply bevelled upwards. Transoms should have their ends tenoned and wedged into the stiles.

550. **SOLID FRAMES ARE PUT IN POSITION** when the steps are set, and the masonry or brickwork is built up round them In cases where the frame is in the middle of the thickness of the wall as at sketch F, Fig. 76, the building in of the horns of the head, and the tenoning of the feet of the stiles into the steps, provides for ample security When, however, the frame is to be flush with the inside of the wall, as at B and C, Fig. 76 it is wise to provide some additional means to hold the frame in The usual way is to nail two or three cleats, of 1" x 1" in cross section, and about 15 inches long, at intervals to the backs of the stiles. The bricks when being built up are cut so as to fit round the cleats. A portion of a cleat is shown at C L, sketch C, Fig. 76 Another very good method is to put bolts through the stiles—the heads being cut in flush with face of stile and the shanks extending out so as to be built into the wall. At least, two bolts should be put from each stile. It is necessary in every case to build a relieving arch (see Fig. 42) above the head of door frame, so as to have as little weight on it as possible.

55 . **LINING BOARDS IN CONNECTION WITH SOLID FRAMES IN EXTERNAL WALLS** —When the door frame is put in, or near the centre of a thick wall, as at F, Fig. 76, the space of the jamb from the inner side of frame to inner surface of wall requires to be covered by what are called *linings*. These are pieces of board (V) Sketch F, Fig. 76, planed up and secured by being tongued into the stiles and head of frame and nailed either to grounds or plugs

552. **SIZES OF SOLID DOOR FRAMES.**—For walls 9 inches thick, the width of the stiles should be from the reveals to the face of the plaster, which, allowing for ¾ of an inch of plaster, would be 5¼ inches ; and the thickness (to suit the best bond for the brickwork, see Arts 189 *ante* and Figs. 33, 34 and 37 on reveals and jambs) without the stop, should be equal to half a brick. Attention to the above considerations would give stiles 5¼ inches wide by 5 inches thick with a rebate ½ an inch deep. As a rule, however, in ordinary work the thickness is made 3½ inches, and the bond of the walling made to suit it The size of the head is generally made the same as that of stiles. In large openings the sizes are made considerably greater than given above

553. **EXTERNAL DOOR FRAMES ARE OFTEN MADE WITH CURVED HEADS,** the form of the curve being either semi-circular, segmental, semi-elliptical or gothic, as the style of architecture may be In cases of this kind the head is cut out of solid timber in two or more pieces according to the size of the opening, and these pieces are joined together either by tenoning and pinning, or by means of the end butt and keyed or bolted joints described in Arts. 422 and 423 *ante*. The whole head so formed is fastened to the stiles in the same way that the pieces are jointed, or by halving and screwing Sometimes a style of construction is adopted for external openings, by which means the outside shows curved while the inside remains square headed. The sketch A, Fig. 78, shows a corner of a frame of this kind. It will be seen that the frame is made with a straight head piece (H) just as in the ordinary frame, the curves being formed by solid pieces which are of a thickness to extend from rebate to outside edge of frame. These pieces are arranged so as to meet at the centre of the head piece, and are housed into the latter and into the stiles. As will be seen by the sketch the curve springs from flush with face of stile and extends to flush with centre of head. The arch marked A R in the sketch is built flush with, and following the curve formed by these pieces. It is the general practice to extend a planted pine stop, ST (bent as required by steaming), round

the soffitt formed by these pieces, as shown by the sketch. But sometimes the pieces are made to project the required amount, and are carefully planed up and beaded on outer edges so as to be the continuation of a stop worked in the solid on the stiles. The doors or fanlights for such frames would be made with the heads actually square to fit the rebate, but the heads of the panels (on the outside at least) would be made to suit the curve (see R Fig. 78, which is a sketch of one leaf of a door for such a frame), while fanlights would be made with the opening for the glass also to suit the curve.

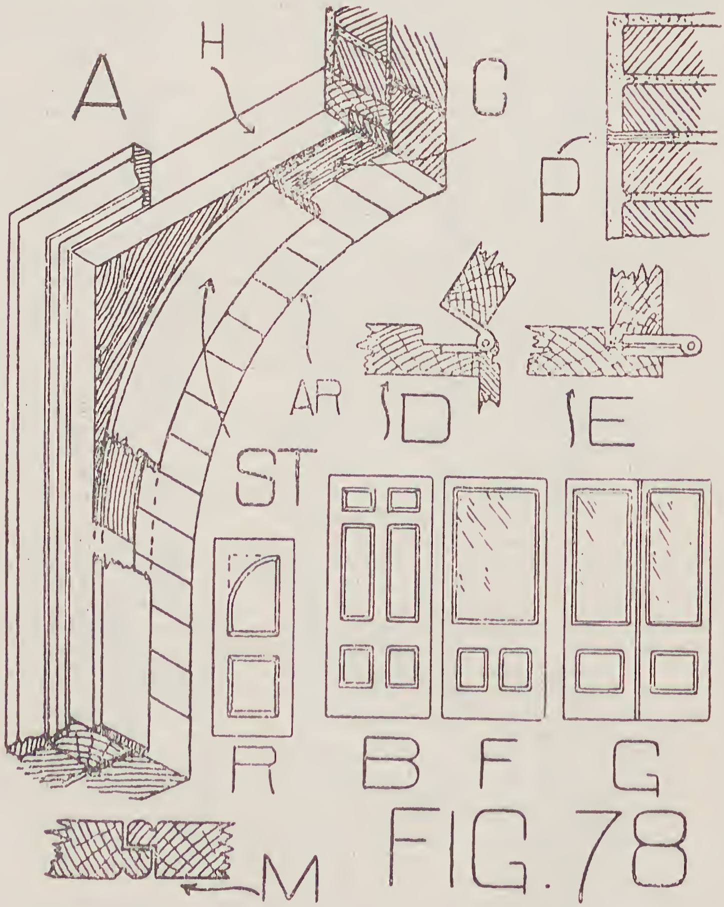


FIG. 78

554. Timber for Door Frames.—The following are some timbers useful for this purpose :—

- (a) Hardwoods :—*Tallowwood*, Red Mahogany, Grey Gum, ***Jarrah***, Forrest Red Gum.
- (b) Timbers of the Soft and Figured Class :—Cedar, ***Colonial Beech***, Rosewood.
- (c) Pine Timbers :—Oregon Pine, Colonial Pine.

Those in italics are especially suitable

555. JAMB LININGS.—The timber linings used to finish the jambs and soffit of a door opening in an internal wall, and to hang the doors to, are called Jamb Linings. This name is indiscriminately given to all linings of jambs of windows and also to inner jambs of external doors as at V, sketch F, Fig. 76. The linings of internal doors are however generally known specially as *jamb linings*, the others as *Linings*. A portion of an ordinary jamb lining for an internal door opening in a 4½″ or 9″ wall is shown at J L, sketch D, Fig. 76. The upright pieces are called *Jambs* while the cross piece or head is known as the *Soffit*. The thickness usually adopted for jamb linings of this kind is 1½ inches, and, as will be seen by the sketch, they are made just wide enough to have the outer edges flush with surfaces of plaster on each side of wall. Though a rebate for the door to fit into is only needed on the edges on one side, it is usual to put a rebate, for the sake of appearance, on the other edges as well. The sketch D shows a *double* rebated jamb. The jambs are tongued into the head as shown by small sketch G, Fig. 76 ; and the whole frame or lining is secured in place before the plastering is done by nailing the jambs to cedar plugs, and the soffitt to the wood lintels under the relieving arch at the head. In the sketch D, Fig. 76, the portion of a transom at its junction with the jambs is shown. The transom would be secured by tenons into the jambs. In the case shown by D, Fig. 76 the preparation of the rebating above the transom would be for a fanlight to hang with hinges at bottom or top. If the fanlight is to hang on pivots the portion of jambs above transom must not be rebated, or the rebate if made must on each side be filled up with a lath. The necessity for this will be obvious, for if the fanlight is to swing on its centre it must be made of the width between the thickest part of the jambs *not* of the greater width between the rebates. For the same reason either the rebate at head of frame or that at top of transom must be omitted.

556. When the openings are in walls of greater thickness than 9 inches the jamb linings should be composed of framing, as linings of great width are apt to warp and split. A bit of a framed jamb lining is shown at J L, sketch E, Fig. 76. Each jamb and the soffit would be framed up with stiles, rails, and panels, as shown by the portion in the sketch—the width and height of panels and the mouldings being the same as in the door. Framed jamb linings are almost always double rebated In superior work the jamb linings are not fixed until after the plastering has been completed, but the grounds G L sketch E, Fig. 76, which are also to provide a precise foundation and good fixing for the jamb linings, are put up before the plasterer commences so as to give him a guide for his work.

557. It may be mentioned that the external doors in stud walls (see Art. 513 *ante*) are generally hung in jamb linings. A method of forming an external door opening in stud walling is shown at sketch C, Fig. 72, in which is the section of the head—K being the soffit of the lining.

558. The following timbers may be used for jamb linings :—FIRST CLASS, OR POLISHED, OR VARNISHED WORK. — Cedar, Blackwood, Rosewood, Red Bean, Colonial Beech, Onion Wood, and others of those mentioned in Art. 355 ante.

ORDINARY OR PAINTED WORK :—Baltic, Kauri, Oregon, or Colonial Pine.

In cases where the joinery work is to be painted the jamb linings are generally made of either Kauri, Oregon, or Colonial Pine.

559. FINISH ROUND DOOR OPENINGS.—In public buildings, and houses of superior construction and finish, the door openings are often finished in a very elaborate manner. Pediments or *overdoors*, supported on pilasters or columns of elaborate design, are used to embellish the openings, and every advantage is taken of the opportunity to make a feature in the internal effect. But this class of work, if only on account of its varied character, is beyond the scope of these articles, and only the ordinary methods of finishing a door opening can be dealt with.

560. The usual method of finish is to put pieces of timber moulding up the sides and over the head of the opening. These mouldings (called architraves) are nailed to edges of jamb linings, and to wood plugs or grounds, and cover the joint between plaster and jamb lining, as shown at A R in sketches D and E, Fig. 76. Sometimes,

however, the architraves are simply pieces of board about 1 inch thick with stop chamfered or beaded edges—an example of the latter being shown at W, sketch F, Fig. 76. Moulded architraves are mitred at upper corners, but those with stop chamfered edges are generally overlapped and halved at top angles after the style of an Oxford picture frame.

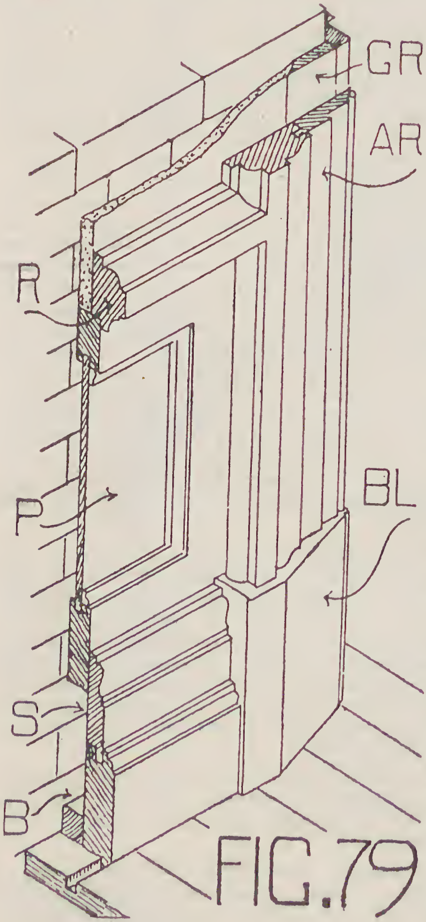


FIG. 79

561. In cases where the skirting is thicker than the architraves a block, as at B L, Fig. 79, must be put to form a stop. The blocks are, however, sometimes adopted, for sake of appearance, where not really necessary. In any case their use may be recommended, for if carried down to the floor the mouldings of the architraves are likely to be damaged during sweeping operations. Architraves are made upwards from about 3 inches wide by 1 inch thick, but in ordinary work they rarely exceed 6 inches wide by 1½ inches thick. When the architrave is so formed as to have one large plane surface back from another, as shown at A R, Fig. 79; it is called *double-faced*. In such cases the the thickness of the architrave varies very much, and in order to avoid the labour of sinking in the solid, and also to gain the advantage of having small pieces of timber instead of one large piece it is made in two pieces which are joined together with tongue and groove and glued. A double-faced architrave built up with two pieces of timber is shown at A R, Fig. 79 Architraves should on no account be fixed until after the plastering is finished The timber for architraves may be, in cases where the work is to be painted, either Redwood, Baltic or Oregon, or Colonial Pine—the former being the best to use. In polished or varnished work the timber for the architraves is made to match the jamb linings, (See Art. 558, *ante*.)

562 (*b*) Doors.—The various kinds of doors may be classified under three heads as follows:—

(1) Ledged and Braced Doors
(2) Framed ,, ,,
(3) Framed and Panelled Doors.

563. Ledged and Braced Doors.—Doors of this kind are made with boards about 6 inches wide and 1 inch thick, arranged vertically and nailed to cross pieces called Ledges, the whole being stiffened with diagonal pieces called Braces. A sketch of a ledged and braced door is shown at sketch K, Fig. 77. The boards should be tongued and grooved together and the joints ornamented (on both sides of the door) with a bead or V. The Ledges (one is marked L G in the sketch) should be placed at the middle and both bottom and top, those at the latter places

being kept about 4 or 6 inches from ends of boards. Ledges are made from 6 to 8 inches wide and about 1¼ inch thick. The braces, B B, sketch K, Fig. 77, should be of the same size as the ledges and should be inclined upwards from the edge that the door hangs at. The boards should be well nailed with two nails into each ledge and brace. Ledged and braced doors are only used for outhouses or parts of a house where strength and appearance are not matters of importance. When a door is made without braces (as is sometimes done) it is called a Ledged door. The omission of the braces is not to be recommended, for without them the door is sure to get out of square

564. **Framed and Braced Door.**—A door of this kind consists of a frame and a covering, or "sheeting" of boards. (See sketch L, Fig. 77). The frame is composed of stiles and rails mortised and tenoned together and stiffened with braces. The boards are tongued and grooved together. and the joints either beaded or V cut ; and when in position the external faces of the boards are flush with faces of stiles and top rail—this means that the bottom and middle rails and braces are to be so much less in thickness than the stiles and top rail. It will consequently be clear that doors of this kind cannot very well be made less in thickness than 2", which gives one inch for boards. and one inch for middle and bottom rails and braces. The rails should. however, if possible, be not less than 1¼ inches in thickness ; so that a good door would be 2¼ inches thick at least. The edges of stiles and top rail should be rebated to receive the boards. and the edges nearest the boards should be beaded, while the edges of stiles, rails, and braces on the inner side will look well if stop chamfered. The braces in this kind of door are not altogether indispensable, though they make a much stronger door. Framed and Braced Doors are strong and well fitted for almost any position where strength is necessary, and where a plain appearance is not objectionable. Church doors are made somewhat like the door just described—the main difference being the curved top part and the omission (as a rule) of the braces, and the boards are usually placed diagonally instead of vertically.

565. **Ledged and Braced, and Framed and Braced Doors** are used only for external openings. for which position they are certainly more suited than the framed and panelled doors Sometimes, however, the ledged and braced door is used for both external and internal openings.

566. **Framed and Panelled Doors.**—A door of this kind (a four-panelled one) is shown by sketch M, Fig. 77. As will be seen, it is composed of stiles (S), bottom rail (BR), middle or "lock" rail (LR), top rail (TR), muntings (MN), and panels (P). A fanlight (FN) and transom (T) are also shown in the sketch, but the present description does not deal with them. Sketches E, F and G, Fig. 77, show to a large scale the methods of tenoning rails into the stiles and the grooving for the panels. E shows top rail tenon with a haunch on upper part. so as to leave some timber of the stile at the head. F shows the middle rail with two tenons and an intervening haunch. The mortise lock is put in the stile so that it will come between these tenons and thus avoid damage to the joint, which would result if the tenons were cut away. G is the bottom rail, which has two tenons and a small haunch at lower part of bottom one, put on for the same reason as given for that on top rail. The thickness of the tenons is made about one-third that of stiles, and all are secured with glue and wedges. The muntings are put in between and stub tenoned into the rails. The inner edges of stiles, bottom and top rails, and both edges of lock rail and muntings, are "ploughed" or grooved about ½ an inch deep for the panels ; these grooves are shown in the sketches. Though the form of door shown at M, Fig. 77, is the most common, the number of the panels is by no means confined to four. For instance, the bottom munting may be left out, in which case the door would have three panels. Again, a *freize* rail is put in below the top rail, as shown at B, Fig. 78, and forms six panels ; and so on according to the taste of the designer. It is well, however, when designing the door to take care to avoid large panels. for the latter are liable to crack and split. The method of finishing the panels determines, in conjunction with the number of them, the name of the door, as for instance, "*Four Panelled, Bead Flush and Square Door.*" is the description of a four panelled door with the panels finished in a certain way. The principal methods of finishing panels in framed work or doors are as follows :—

567. **Square and Flat Panels.**—This is the name given to the panels when less in thickness than the framing, and finished as let into the frame without any mouldings. See sketch A, Fig. 77. (Sometimes the edges of the frame are ornamented with a stop chamfer, in which case the finish might be called—"*Square and flat panels with stop chamfers.*"

568. **Moulded and Flat Panels.**—Where the panel described above is finished with small mouldings put in, or "*planted*," round the panel and up against the frame, the finish is called *moulded and flat*. This finish may be on one or both sides of the panel. The moulding may be sunk or planted after the style of that shown at R, or the protruding kind known as Bolection moulding, S, Fig. 75.

569. **Bead Butt Panels.**—See sketch B, Fig. 77. In this case the face of the panel is flush with the face of the frame; the edges adjacent to the stiles being being beaded, while those against the rails are closely butted. The portion of panels going into the groove in the frame, forms, in this style, a tongue. The bead butt finish may be on one or both faces of panel. When on both faces the panel will be of the same thickness as the frame. As a rule, however, this finish is put on one side only, the other being square and flat, or square and moulded.

570. **Bead Flush Panels.**—This kind of finish is much like that above; the difference being that the bead is carried all round the edge of the panel. See sketch C, Fig. 77, what was said about bead butt on one or both faces applies equally to this kind.

571. **Raised and Moulded Panels.**—This kind of panel is thicker in the middle than round the edges—the part round near the framing being flat and the centre being raised in the form of a "full" or "truncated" pyramid. The moulding is generally the kind known as "bolection." A corner of a raised and moulded panel is shown at D, Fig 77. The panel may be raised on one or both faces of the panel. As a rule, however, the raising is on one face only, the back left flat and sunk moulded, as shown in the sketch.

572. **Panels** should not be fixed with either nails or glue, but should be left so that movement due to shrinkage or swelling may take place freely, and without causing cracks. For the same reason the planted or bolection mouldings should not be nailed to them, but to the framing.

573. **Doors Made in Leaves.**—If the width of the opening is 3′ 6″, or more, the door should be made in two pieces or "leaves," as they are called. This is necessary because if more than about 3 feet in width the tenons in the hangings stile are stressed too heavily and are apt to give. Convenience of opening also demands, in most cases, that the door would be too wide. Each leaf is the same as a single door in construction and general appearance, except that in most cases the muntings are left out, thus providing for the same number of panels as if the door were made in one piece. The edges of the leaves where they meet in the centre are rebated and beaded, as shown at M, Fig. 78. In cases of very wide door openings, such as those which are used to form two rooms into one as occasion requires, the doors are made in four, or even more, leaves. The leaves are divided into two sets —those in each set being hung to each other—the outermost in each being hung to the jambs. The width of each leaf in the case of folding doors should not exceed 2 feet. The edges of leaves where hung to each other, and where meeting at the centre, should be rebated and beaded, as at M, Fig. 78. The leaves should be so arranged and hung that they fold back on each other when opened back. Doors made in a number of leaves are never a great success, for the leaves furthest from the jambs have a tendency to drop or "sag." To get over the difficulty with wide openings, a better way is to have the whole door made in two leaves only—each being suspended by straps to flanged wheels which run on overhead rails or bars—the opening of the door being performed by pushing the doors on the wheels into cavities in the wall on each side.

574. **Sash Doors.**—Doors made with upper part in one panel, and the latter filled with glass, are called "sash doors" (see F, Fig. 78). It is usual in these doors to make the width of the upper part of stiles less than the lower part—the difference in width in each stile being made in the part between the top and bottom of the lock rail by having the shoulders of the latter slanting instead of square. The stiles in such cases are called "diminished stiles." The upper edges of the stiles, and that of top rail, are either rebated for the glass and moulded like

a sash (see Art. on Sashes). or provision for fixing the glass by beaded fillets is made; the latter is by far the best way. Sometimes sash bars are put in so as to divide the upper panel into a number of parts—a favourite style of division being to put a bar about 4″ in from from the edge of panel right round, thus forming a margin round a centre pane. The margin is divided by cross bars at intervals. A door of this kind is called a "*Margin Light*" door. A kind of door called a *Casement* is shown at G, Fig. 78. This is very much used for openings in external walls leading on to verandahs. As will be seen by the sketch, it is really a sash door made in two leaves, each having upper panels of glass and diminished stiles. In the sketch the lock rails are shown at the same height as in other doors, but, in many cases they are put very much lower. It is, however, very unwise to put them any lower than the top 2″ 6″ from the floor. Casements and sash doors, if put in external openings may have outer faces of lower panels raised and moulded with inner faces flat and moulded. Casement doors should never be put in external openings unprotected by verandahs or covered balconies, and, even then should have the protection of shutters. It is a general custom to put wood sills (like those for sashes) fitted with water bars at the feet of these doors, but as the doors open inwards the bar is not of much value, and consequently the sill is next to unseless.

575. SIZES OF DOORS AND THEIR PARTS.—Doors or openings for the passage of people should never be made less in width than 2ft. 6in., not less in height than 6ft. 6in.. while the thickness should not for the sake of good construction be less than 1½in. in any kind of framed doors. The corresponding sizes of width, height and thickness in ordinary doors are as follows :—

WIDTH.	HEIGHT.	THICKNESS.
2ft. 6in.	6ft. 6in.	1½in.
2ft. 8in.	6ft. 8in.	1¾in.
2ft. 10in.	6ft. 10in.	1¾in
3ft. 0in.	7ft. 0in.	2in.
3ft. 6in.	7ft. 0in.	2in.
4ft. 0in.	8ft. 0in.	2¼in.

The parts of ordinary doors are made of the following sizes :—

STILES	4½ inches wide	All being of the same thickness.
MUNTINGS	,, ,, ,,	
TOP RAIL	,, ,, ,,	
LOCK ,,	9 ,, ,,	
BOTTOM ,,	,, ,, ,,	

576. Panels should never be less than ⅝in. but generally are ½in. thick. The upper part of stiles and top rail in sash and casement doors are from 2¼in to 3in. wide. The top of the lock or middle rail is in ordinary practice put at from 3ft. to 3ft. 3in. from the bottom of the door.

577. TIMBER FOR DOORS.—The following are some timbers which are suitable for this purpose :—

LEDGED AND BRACED AND FRAMED AND BRACED DOORS — Baltic Pine, Oregon Pine, Redwood or Colonial Pine.

FRAMED AND PANELLED DOORS.—*Painted Work.* Baltic Pine, Redwood, Clear Fine, Sugar Pine, Kauri Pine and Colonial Pine.

Polished or Varnished Work. Blackwood, Cedar, Rosewood, Colonial Beech, Kauri.

578. GLUEING AND WEDGING UP A DOOR.—The stiles, rails and panels should be loosely framed together and allowed to stand for a time before being permanently tightened up and fastened. The latter work is done on the bench as follows :—The door as loosely framed is put resting on bearers which are "out of wind," that is to say, the upper edges of all are in the one plane. The tenons are exposed and painted, as well as the mortises, with glue. The whole is then knocked together with hammers and finally tightened with "cramps"; wedges, also painted with glue, are then driven in at edges of the tenons. Great care should be taken to drive the wedges on each edge as equally as possible to prevent breakage of tenons. The cramps are next removed and the whole of each side of door planed to a fair surface and glass papered until quite smooth. Mouldings (if there are to

be such) are then cut into the panels and "bradded," that is, nailed with thin nails or "brads" to the stiles and rails. The ends of the stiles longer than necessary are not cut off until when hanging the door.

579. HANGING OF DOORS.—The operation of fitting a door into the frame or jamb lining and fitting and putting it on to hinges, is called "Hanging." The fitting in the rebate of frame or jamb lining should be done with as much accuracy as possible, and it goes without saying that the better the door and frame the better the fitting should be. In the case of the Ledged and Braced door described in Art. 563, the amount of space between the rebate and edge of door would not be so small as is the case of a good framed and panelled door for an internal opening. In any case, however, the smallest possible space compatible with easy opening and shutting should be arranged for. In the best kind of work the space is very little —indeed there is practically speaking hardly any at all. In ordinary work the space is about what the edge of a half-a crown piece would fit in. In ledged and braced doors it is oftener about $\frac{1}{4}$ of an inch than less. The foregoing refers to the joint at sides and top; the joint at the foot is of course necessarily bigger, for even in superior work the doors have to open back over thick carpets, etc., and allowance must be made accordingly. But no more than is absolutely necessary should be allowed, for a big space under a door induces most uncomfortable draughts. To fit and hang a door with the minimum amount of joint space is only possible when the door is made of seasoned timber not liable to shrink or swell. Most of the machine made doors in use are made of an American pine which shrinks and swells with change of weather and as a result a door is tight so as to stick one week and the next is so loose as to appear very bad. Ledged and braced doors are hinged on T hinges. The framed and braced are also at times hung on these hinges, but when strength is required the hinges are either those shown at F, Fig. 74 or what are called *butt hinges.* Framed and panelled doors are always hung on *butt hinges.* An example of the latter kind is shown at D. Fig. 78. As will be seen, they fit into the edge of door and in the rebate of frame or lining. They range from $1\frac{1}{4}$in. to 6in. in length, and are made in brass or iron. The round part, where the centre of revolution is, is called the "knuckle." In ordinary work two of these butts are used (in good work, three) to hang a door from 6ft 6in. to 7ft. high, the positions being one at level of top of bottom rail, one at level of bottom of top rail, and the third (if such there be) central between the other two. The usual way is, as shown, to sink the hinge the depth of the thickness into edge of door, and into rebate of frame or jamb lining. When the door is required to open back, and clear a projection, such as a thick architrave, the knuckle must be put well out, as at E, Fig. 78. Each flap of the butt is secured with 3 or 4 screws into edge of door or rebate. Doors should always be hung inwards to a room, and should be hung on the edge that will allow of its covering the most of the most of the room when partly open. Doors of public buildings and churches, etc., are exceptions to the rule of opening inwards, for owing to the danger of panic they should open outwards so as to prevent any chance of their becoming fast from a pressure inside as would very likely occur if hung to open inwards.

580. FANLIGHTS.—These are sashes put over doors to give extra light and also to provide means of ventilation. They are made much in the same way as sashes. (See Clauses on Sashes), with stiles and top rails from $2\frac{1}{4}$in. to 3in. wide, and bottom rails a little wider; the thickness being the same as the door. They are sometimes fixed tight in place, but as a general rule they are made to open and shut so as to give ventilation. When made to open and shut they are hung either with butt hinges on the bottom edge, or on pivots at about the centre of the stiles. In the former case they are made to fit into the rebates above transom; but when pivots are used the rebates are filled up (or else not made at all in the upper part of the sides of door frame or jambs) and the fanlight is made of the width between the stop faces of jambs or frame, so that in opening either the upper or lower part (as may be arranged) shall be able to swing in between. It is also necessary to note that when the fanlight is hung on pivots the transom is made without a rebate on top, so that the bottom part of fanlight may be able to swing clear in an outward direction. Pivots consist of what may be called bolts and sockets. The bolt is a pin about $\frac{1}{2}''$ diameter fastened to a plate which is secured with screws to the sides of sash. The pin or bolt works, or revolves, in a hole in a socket plate

which is secured to the jambs or side of frame. The socket plates are made with a slot the same width as the diameter ; these slots lead down to the holes in which the pins work ; consequently the sash or fanlight may be removed bodily if required by lifting it so that the pins come up by way of the slots. Pivot hung is the best way for fanlights over internal doors.

WINDOW OPENINGS.

581. THE JOINERY WORK connected with window openings consists of the following :—

(1) Frames.
(2) Sashes
(3) Finishing Round Frames

582. WINDOW FRAMES.—These are either

(a) Boxed
or (b) Solid.

583. BOXED WINDOW FRAMES.—A Frame of this kind may be said to consist of sill, side casings, and head. The sill is made of hardwood, and is from 3 to 4 inches at the thickest part, and of the width of the side casings. Cross sections of sills for Box Frames are shewn at R, Fig. 47, and W S Fig. 80. A better view is given at A, Fig. 69, which shows a sill finished much in the same way on the top surfaces as one for a box frame. It will be seen by the sketches that the top of the sill is formed with a level portion about one inch wide at inner edge, and the rest in two or three stepped slopes. The step, or portion forming the rise between the slopes, should be hollowed out or "throated." The slopes are called "weatherings" The object of the weathering and the throating is to get the rain water away as quickly as possible and to prevent it from getting in under the sash. To fully accomplish this it is necessary to work the sill, as shown in the sketches Figs. 69, 80, and 81, with three slopes—two of the latter and a stepped throat being under the sash. In unimportant work the sill is made with only two slopes as at R, Fig. 47. The side and head casings are much alike. A cross section of a side is shewn by sketch C, Fig. 80, while the section of a head is depicted in the large sketch, Fig. 80. The parts of the casings are as follows :—

584. PULLY STILES.—These are the pieces of timber (P.S.T. sketches B, C and D, Fig. 8) against which the edges of the sashes abut and slide. They also contain the pullies (P Y) sketch B over which the hanging cord passes, and are grooved to receive the parting bead (P.B. sketch C Fig. 80) The lower ends of the pully stiles are housed and wedged into the hardwood sill, as shown at sketch E, Fig. 81. The *head* (H, Fig. 80) of the box frame is of the same cross section as the pully stiles, and grooved, and otherwise prepared much the same, excepting that there are no pullies or pockets. Pully stiles and heads are made as a rule, 1in. thick.

585. INNER AND OUTER FACINGS.—These are pieces of timber put on to form the backs and fronts of the casings. These pieces are frequently called linings, but, so as to distinguish them from the linings used for internal finishing it is best to call them *facings*. The outer facings (O F, Fig. 80) are made wide enough to project about ⅝in. to ¾in. in front of the face of the pulley stiles, so as to form a guard to keep the top sash in place. The inner facings are, however, not so wide—the edges being kept flush with the faces of pulley stiles. The thickness of the facings varies from ⅞in. to 1in, according to the class of work. In common construction the facings are only nailed to the pulley stiles, but for good work the joint should be made with tongue and groove, as shown in the sketches. The facings are put to the head of the frame just as to the pulley stiles. (See sketches)

586. BACK LININGS.—These are the pieces of timber put at backs of side casings to keep mortar, etc., from getting in. A back lining is shown in sectional plan at B L, sketch C, Fig. 80.

587. STOP AND PARTING BEADS.—These are the strips, beaded on outer edges which are used to keep the sashes in place. The parting beads (P B, Fig. 80) are let into grooves in the pulley stiles and head and are placed so as to keep the sashes apart. The stop beads (S B, Fig. 80) are nailed to edges of casings, head and sill on the inner edge of the frame, so as to keep the inner or bottom sash in place.

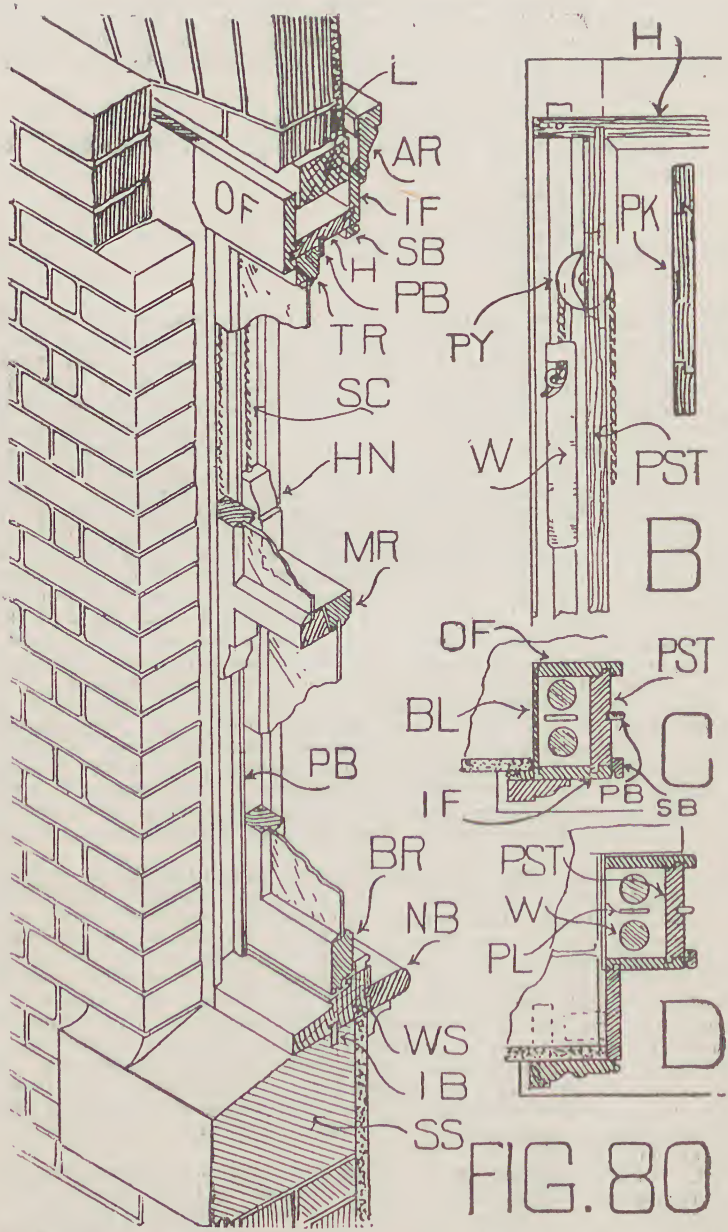


FIG. 80

588. Solid Window Frames.—The large sketch Fig. 81) is a vertical section of a window opening with a solid frame. W.S. is the sill, which, it will be noted, is made like one for a box frame. H is a cross section of the head, and the stiles

would be of similar shape The stiles would be housed and tenoned into the sill and tenoned into the head. As will be seen, the stiles and head are rebated to receive the sash which, in the case illustrated, is arranged to open outwards—this being the best way. If the sash is to open inwards, the rebate must be put on the inside, and the sill shaped a little differently so as to guard against the inroad of the rain water. In the example given the outer edges of the stiles and head are moulded, but, as a rule, the edges are merely headed, as in the case of a door frame

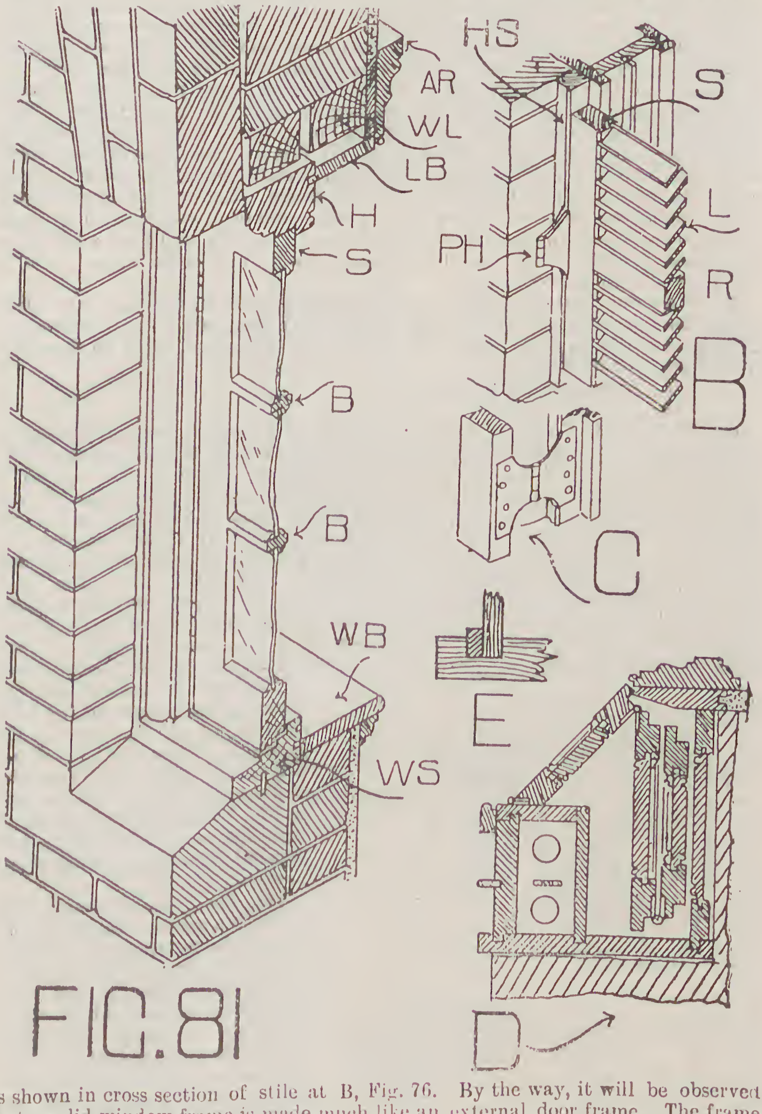


FIG. 81

as shown in cross section of stile at B, Fig. 76. By the way, it will be observed that a solid window frame is made much like an external door frame. The frame in Fig. 81 is for sash hung at side (if in one leaf, or at sides if in two), with butt

hinges. In the case of the sash being hung on pivots, as is sometimes done, the rebate would be formed with stops as described in Article 580 *ante.*

589. Timbers for Window Frames.—The timbers set out in Art. 554 *ante* for door frames may be taken as also suitable for solid window frames. As before remarked, the sills of the boxed frames should be of hardwood, if possible. The other parts may be of the same kinds as set out in Art. 558 *ante* for jamb linings, but redwood may be added to the list.

590. Fixing of Window Frames.—Solid frames are almost always set in during the building of the wall, and fastened in the same way as described for a door frame. Boxed frames in ordinary building are also built in the walling, but in superior work they are put in after the walls and roof have been completed. It will be obvious that the latter way is the best, for the frame escapes the damage which is inevitable if put in when the masonry or brickwork is being done. When built in, the ends of the sills are bevelled like the head of a door frame, so as to improve the hold in the wall. Wood lintels (L, Fig. 80, and W.L., Fig. 81) should in all cases be put over frames, to carry the overhead brickwork, but, in no case should the lintel be allowed to bear on head of frame. The sketches, Figs. 80 and 81, show relative positions of the lintels. A water bar of galvanised iron or copper should be put so as to project into both stone and wood sills, and form a barrier to the passage of water. The wood sill is generally bedded on to the stone sill in a thin layer of cement mortar.

591. Window Sashes.—A sash is a light frame containing the glass, and fitted so as to hang or slide in the " solid " or " boxed " window frame. The construction of sashes depends upon the kind of window frame, hence they will be described under the following heads :—

(a) Sashes for Boxed frames.
(b) ,, ,, Solid ,,

592. Sashes for Boxed Window Frames.—For boxed frames the sashes are made in two pieces known respectively as top and bottom sashes, and hung with cords and counter weights so as to slide up and down. Portions of a sash for a box frame are shown in position in the large sketch, Fig. 80. The stiles of each sash and the top rail of top one are alike in width, while the bottom rail of the bottom sash is wider, and the connecting rails narrower than them As shown by the sketches the stiles in each sash are extended past the meeting rail and finished with a moulding—such extensions being called " Moulded Horns." The horns give finish to the stiles and also provide for stability in the joint with the meeting rails. The latter are generally bevelled at the meeting surfaces, as shown in the sketch, but in superior work the junction is made with a bevelled rebate. It will be noticed that the sashes are kept apart by the thickness of the parting beads (P.B.), but the meeting rails are wider by the amount of the bevel so as to fill up the space at this junction. The under edge of bottom rail of lower sash is rebated and bevelled and grooved, as shown in Fig. 80, or simply bevelled, as the importance of the work may demand. The best way is as shown in sketch Fig. 80.

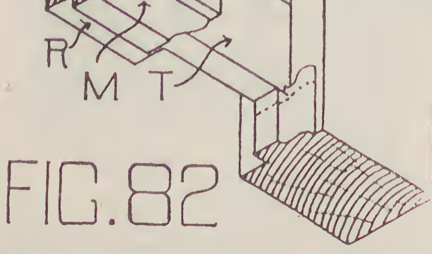


FIG. 82

593. The glass is secured with putty in a rebate, excepting in the case of the meeting rail of bottom sash, which has a groove, to take the glass, formed in the outer edges of the frames, while the inner edges are moulded. The sketch Fig. 82 shows a top corner of a top sash just as it is being put together. R.L. is the rail with tenon and hunch, and the moulding scribed already to fit into and against the stile S.T. The other joints are made similarly

—a slight difference only in the case of the meeting rails—the hanching (if done as shown in Fig. 80)not being necessary. It may be remarked that the sashes are made so that when together, as in the drawing, the meeting rails are in the centre of the height between the top of bottom rail and bottom of top rail. In the example illustrated each sash has only one pane of glass. Sashes are not, however, always so made, for, it is often the case that each has two or more panes. The divisions are formed by narrow pieces, each rebated and moulded like the stiles and rails, and called *Sash Bars*. (See B in large sketch, Fig, 81.) The bars are arranged horizontally and vertically, as the division may be (if there are bars both ways one would run right through while the others are formed of pieces put in between), and the joints with sashes and with each other are made with tenons and scribed intersections, as in the case of the stiles and rails. The bars are frail, and, in the case of a sash with a large number of divisions, a considerable amount of skill is required to get all equal and all perfectly straight. Sashes are generally made from $1\frac{1}{2}''$ to $1\frac{3}{4}''$ thick, but in large windows the thickness is much greater. The following are sizes of cross sections of parts of sashes for all ordinary sized windows :—

	Thickness.		Width.
Stiles	$1\frac{3}{4}''$	x	$2\frac{1}{4}''$
Top Rail	„	x	„
Bottom „	„	x	$4''$
Meeting „	$2\frac{1}{8}$	x	$1\frac{1}{2}''$
Bars	$1\frac{3}{4}$	x	$\frac{7}{8}''$

594. The joints of the sashes are glued and the tenons secured with wedges, after which the faces are cleaned, or planed off, and sand-papered. The glass is next put in, and the sashes are then ready for fitting and hanging in the frame. The fitting consists of planing off the superfluous width so that the sashes may slide up and down easily between the pulley stiles, and in cutting off the rough horns at top of upper and bottom of lower sash and fitting so that meeting rails come together, and the bottom rail fits the sill. The outer edges of each sash are next grooved for some distance back from the horns at the meeting rails. These grooves are to take the sash cords. The process of hanging briefly described is as follows :—The top sash is taken first and weighed, and selection made of two weights, the combined weight of which is equal to that of the sash. The pockets in the pulley styles are removed and the sash cords passed from the outside through over the pullies ; the inner ends brought out again by way of the pockets, threaded through the tops of the weights, and secured in each by a knot. The weights are then pulled in through the pockets and up to near the pullies or the inside of the pulley stiles, after which the other ends are secured with clout headed nails in the grooves on the edges of the sashes. Allowance is of course made for the full amount of slide down of the sash ; that is to say, provision is made so that when the sash is as low down as it can go the weights on the inside shall not have quite reached the pullies. Again provision must be made that when the sash is up at the top the nails used for securing the cord to the grooves shall also be not quite up to level of pullies, otherwise they would prevent enough of cord passing through to allow of full upward slide ; when the top sash is hung in place, the pockets are put in and the parting beads are put in. It should be mentioned that portions of the bevel at the ends of the meeting rails of each sash are removed so as to allow of sliding past the parting beads. The bottom sash is then hung in the same way, but it must be remembered that the weights for this sash must be put in before the pockets are replaced. The stop, or inner beads (SB) are finally put in. Sketch B, Fig. 80, shows a balance weight (W) pulley (P Y) and sash cord. The balance weights are of cast iron, and made in weights from 2lb. upwards. Sash cord is a superior kind of hempen rope of small diameter. Before being used it should be well stretched, otherwise it will become loose afterwards. Considerable trouble is caused by replacing breakage of the cord, and to meet the difficulty a metallic flexible sash line can be obtained which serves well and is durable beyond question.

595. Sashes for Solid Window Frames.—These are called casements. They are made in either one or two leaves ; and the stiles, top and bottom rails and bars are similar in size and shape of cross section to those in sashes for boxed frames.

The jointing is also on the same principle. They are hung like a door with butts to the stiles of the frame, and are arranged as a rule to open outwards The example in large sketch, Fig. 81, is one to open outwards. This way of opening is far the best, it being possible to fully guard against the inroad of the rain water. Sashes are, however, sometimes made to open inwards, in which cases the rebate to receive them must be on the inside of frame and special provision made if the window is exposed, so that the junction of bottom rail with sash shall offer the best resistance to weather. If the sash is made in two leaves the meeting stiles are rebated and beaded as shown for a door at M, Fig. 78. Sashes for solid frames may be hung on pivots as described for a fanlight.

596. SASHES WITH CURVED HEADS.—The examples given are rectangular in shape, but the form is by no means restricted to this, for sliding sashes are made not only with curved heads but also with curved faces, and those for solid frames may be of any shape. It is not possible to say more of these curved sashes than to mention that the pieces are as a rule jointed with butt joints, and secured either with the key shown at A, Fig. 49A, or with the screw described in Art. 423 ante.

597. TIMBER FOR SASHES.—The following kinds of timber are used for sashes :—

PAINTED WORK.—Baltic Pine, Oregon Pine, Clear Pine, Sugar Pine, Kauri Pine, Colonial Pine and Redwood.

POLISHED OR VARNISHED WORK.—Cedar, Rosewood, Blackwood, Colonial Beech and Kauri.

598. FINISHING ROUND WINDOWS.—This part of the work can be best dealt with under two heads as follows :—

(1) When frame is flush, or nearly so, with inner surface of wall.
(2) When frame is not flush with inner surface of wall.

(1) The first case is that mostly met with, being the finish for walls 9″ thick, and consequently the kind, as a rule, in ordinary house building. A piece of board from 2 to 3 inches wide with nosing on edge and at both ends, is put either with a groove into sill or just butted to sill. This is called a *nosing* (see N B, Fig 80). A Scotia or ovolo moulding, also with returned ends, is put under the nosing The nosing is extended on each side of the frame to receive the ends of the architraves, which are put up the sides and over the head as in the case of a door (see Art. 560 *ante* re architraves). If the sashes in the case of a box frame are thicker than 1½″ the frame will project out from inner surface of the plastering. This will render necessary a fillet to fill up space between back of architrave and wall. The fillet should be beaded on outer edge. See sketch, Fig. 80, which shows finish on inside of box frame. A solid frame could be finished similarly with the exception of the fillets at backs of architraves which would not be necessary.

599 (2) WHEN THE FRAME IS NOT FLUSH WITH INNER SURFACE OF WALL, that is to say, when it is back therefrom. In this case, which occurs in thick walls, lining boards (L B, Fig. 81) are necessary. The lining at the sill is called the "Window board" or "Nosing board" and is wider than the others, being arranged like the nosing to project out from wall and extended on each side to receive the architraves. The linings at sides and head are only wide enough to come to edge of wall and may be plain as shown in the sketch or pannelled. Window linings are made much the same (the main difference being the absence of rebates) as those for doors and are fixed in the same way (see Art. 555 *ante* and Fig. 76). They are grooved into the frame and fixed to grounds at outer edges. The large sketch, Fig. 81, shows linings to a solid frame but can also be taken as illustrative of the finish in the case of a box frame, for there would be no material difference were it the latter. The architraves are fixed to grounds which support the linings. In the example Fig. 81 the linings are square, or at right angles, with surface of wall. In some cases they are put on the bevel outwards from face of frame. These are called "splayed linings"; when the head of frame is curved the head lining is also of similar curve. The curved piece in such work is generally formed of a thin veneer with backing of wedge shaped pieces, the whole being glued together.

A very convenient and effectual method of finishing a window opening in a thick wall is to have the part of wall under the window flush with the inside of latter, thus rendering a window board unnecessary. In such a case the side linings

would be carried down to the floor; the space under window being either plastered or covered with a pannelling.

600. ARCHITRAVES FOR WINDOW OPENINGS.—The inmost edges of window openings are finished with architraves (A R) as shown in sketches Figs. 80 and 81. The architraves are similar to those described for door openings in articles 560 and 561 *ante*, and fixed much in the same way. Where there are either nosings or window boards the architraves are butted or stopped on to them.

601. TIMBER FOR LININGS AND ARCHITRAVES OF WINDOW OPENINGS.—The timber used for these parts are usually either Redwood, Kauri or Colonial Pine in cases where the work is to be painted. Any of the timbers mentioned in Art. 558 as suitable for jamb linings will, however, do. In cases where the work is to be polished or varnished the timbers for door and window openings and other internal fittings should be selected with a view to a pleasing effect as a whole.

602. SHUTTERS are framed covers or screens used for window and casement openings to afford either shade from Sun, protection from the rain, or resistance to fire or robbers. They are made in either one or more leaves, and are either hung like a door or made to slide either into cavities at either sides or above or below opening. They may be divided into two kinds:—

(1) External shutters.
(2) Internal „

603. EXTERNAL SHUTTERS.—These are sometimes made like either a *framed and ledged* or a *bead and flush panelled* door with the timbers very thick so as to resist violence, or very rough weather. Outside shutters are also where extra strength is required, or where protection from fire is needed made of stout iron plates. The latter are, however, only used in large buildings subject to extra risk from fire in dangerous parts of cities while heavy wooden shutters are very seldom used in house building because the object as a general rule is only to provide shade from the sun and protection from rain. Sketch B, Fig 81, shows portion of a shutter of the kind generally used. They are made generally in two leaves each of which is a light frame filled in with slanting laths or "louvres." In cases where the window is of ordinary size there would be a top, middle, and bottom rail in each leaf but for casement and other openings of fair height sufficient rails would be put in between top and bottom to allow of a spacing apart of about 3 feet. The stiles (S) and top and intermediate rails (R) would be about $2\frac{1}{2}'' \times 1\frac{3}{4}''$ in cross section, while the bottom rails would be from 6″ to 9″ wide and the same thickness as the others. The louvres (L) are generally $\frac{3}{8}''$ thick and of a width sufficient to give enough of cover, one over the other; and they are housed for about $\frac{1}{4}''$ into the stiles. The edges, next the louvres are on both sides of the frame beaded. Louvre shutters, as they are called are hung to small pieces of timber about $1\frac{1}{2}'' \times 1\frac{3}{4}''$ (see H S, sketch B, Fig 81) in cross section, or whatever may be the thickness of the shutters, which are secured with screws to the outer facing of box frame or to stile of solid window frame or casement door as the case may be. Head pieces of the same scantling are fixed at head of frame and connected to tops of side pieces with a butt and mitre joint. These side and head pieces are called "Shutter hanging stiles and heads." The shutters should be hung so as to open back against the outer face of wall. To accomplish this a kind of hinge known as a "Parliament hinge" and shown at P H, sketch B, and at sketch C, Fig. 81, must be used.

604. TIMBER FOR LOUVRE SHUTTERS.—Cedar, Baltic Pine, and Redwood are good kinds for the frames; while cedar or baltic pine are suitable for the hanging stiles and heads. Redwood is by far the best for the louvres.

605 (2) INTERNAL SHUTTERS.—These are generally made in very narrow leaves, each of framed and panelled construction, which are hung together in two sets like folding doors. They are made to hang this way so that they may be folded back into boxes or casings at each side of the opening and consequently be out of the way when not in use. A sketch showing a horizontal section through the side of a window opening with a box frame fitted with internal folding shutters folded back in the casing is shown at D, Fig 81. Shutters also of framed and panelled construction can be made of the size of the sashes and arranged to hang like the latter in a second box frame inside that for the sashes, and disappear when

not in use into a cavity at foot or head of opening. Internal shutters are hardly needed, and indeed are very seldom used in the climate of this country.

606. SKIRTING.—The boards put round to cover the joints of the walls with the floor, and to form a base for the walls are called skirting boards. In design the skirting boards may, according to circumstances, be either *plain*, *moulded*, or *double-faced and moulded.*

607. PLAIN SKIRTING consists of a piece of board about 6 inches wide and 1 inch thick, with the top edge either chamfered or beaded. *Moulded skirting* ranges from about 7 inches to 9 inches wide, and has an ogee or ovolo, or some such moulding on the top edge. Sections of moulded skirting boards are shown at R, Fig. 54, and at SK sketch, D, Fig. 72. *Double faced and moulded skirting* is the most elaborate form. The name, double faced, is given because the face of the board has two large plain surfaces. This kind is generally made in two pieces, so as to obviate the disadvantage of having one large piece of timber, the pieces being grooved and tongued together as shown at S, Fig. 79, which illustrates a double faced skirting.

608. TIMBER FOR SKIRTING BOARDS.—In polished or varnished work the timber used for skirting is generally the same as that in the architraves. Pine timbers such as redwood, kauri, baltic or oregon are used when the work is to be painted.

609. FIXING SKIRTING BOARDS.—As a rule, skirting boards after being scribed so that the lower edge fits the floor, are secured to walls with nails driven into grounds or plugs, the latter being spaced not more than 18 inches apart. The lower edges should not be nailed to the floor because of the danger of splitting the skirting boards if shrinkage should take place. In the best class of work the skirting boards are grooved into the floor as shown in Fig 79, thus providing for movement due to shrinkage as well as helping to keep the skirting in place.

610. SURBASE AND DADO.—A *surbase* consists of moulded railing put round the walls at from 2ft. 9in. to 4ft above the floor. The *dado* is the portion of wall surface, or boarding, or panelling, between the skirting and the surbase. In large public buildings the skirting dado and surbase become imposing features, and the height of the surbase is often much more than 4′ 0″. The dado, as a general rule, is composed of 6″ x 1″ or 4″ x 1″ T. and G. and B. boards either diagonally or upright, and nailed to framing of grounds. The sketch, Fig. 79, shows a dado of framed and panalled work with a double-faced skirting and a moulded surbase. A dado may be formed with the wall surface and a timber skirting and surbase. This is an inexpensive form, and if the walls be papered a very good effect can be got by putting strong paper with relieved pattern, such as "Lincrusta-Walton," for the dado. The surbase is often made quite plain (*i.e.*, a plain board about 3″ x 1¼″ with beaded top and bottom edges), and put low enough to catch the tops of backs of chairs. In such cases it is put up mainly with the object of preventing damage to the walls, and is called a *Chair rail.* It is worth mentioning that in internal decoration the term "dado" is often meant to include the skirting and surbase as well as the dado proper. Skirtings, timbers, dados, surbases, and chair rails should be fixed after the plastering is completed.

611. PICTURE RAILS are pieces of moulded timber put round the upper part of walls at the level of the head of door architraves, or higher according to taste. They are used as their name implies—to suspend the pictures from. They are also as a rule considered as a part of the internal decoration, and made to form the lower edge of a freize which extends upwards to the ceiling or cornice.

STAIRS.

612. SERIES OF STEPS for ascending from one storey to another in a building are called *stairs.* The *staircase* is the structure surrounding or enclosing the tairs. *The kinds of stairs* are as follows :—

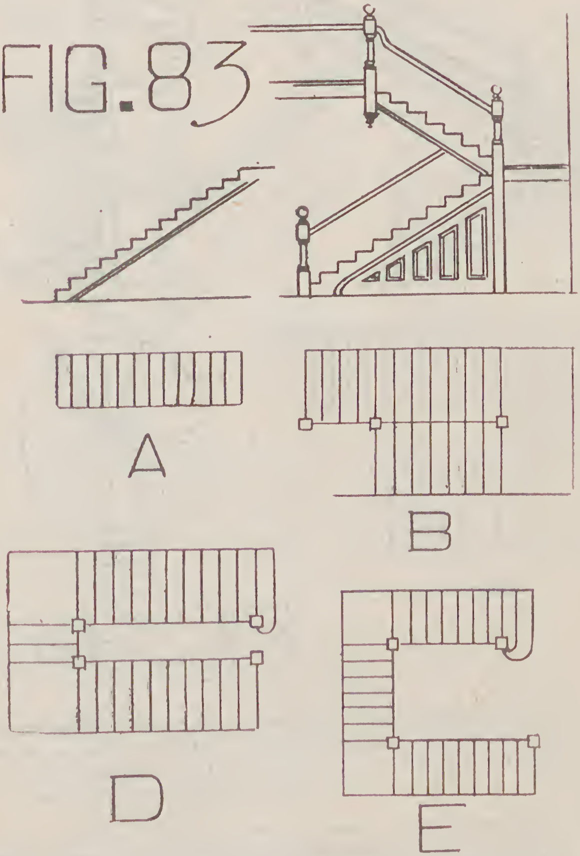
(*a*) Straight	See A	Fig. 83	
(*b*) Dog-legged	" B	"	"
(*c*) Open Newel	" D	"	"
(*d*) Geometrical	" A	"	84
(*e*) Circular	" B	"	"

Note.—The various sketches showing the different kinds of stairs in Figs. 83 and 84 are merely diagramatic—all details being omitted.

613. A STRAIGHT STAIR is shown at sketch A, Fig 83. As will be seen it consists of a number of steps one above the other, and rising in the one direction. This kind is useful only when the total rise is small, because if the stair is a long one they are tiring to ascend, and besides, they require a lot of room for the "going." If, however, "landings" be put in so as to divide the total length into short flights, the straight stair can be made easy of ascent and also a very imposing structure.

614. A DOG-LEGGED STAIR is shown at sketch B, Fig. 83. This kind of stair is divided into two flights going in opposite directions. A stair of this description

FIG. 83



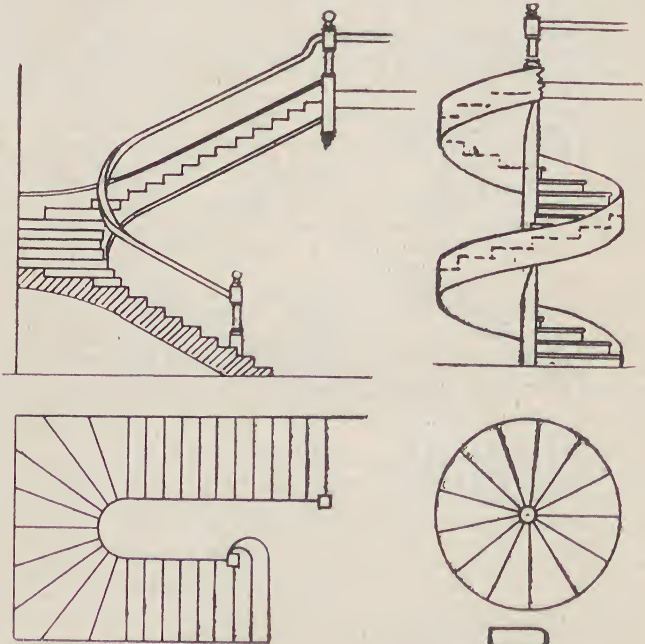
may have either a landing as shown in the sketch or "*winders.*" Winders should however if possible be avoided, for at the best they are uncomfortable if not positively dangerous.

615. OPEN NEWEL STAIR.—Sketch D, Fig. 83, shows an example of this kind of stairs. It will be seen that it consists of two flights in opposite directions like the dog-legged stair, but it differs from the latter inasmuch as that the "outer" strings are not one directly above the other, consequently it requires two newels at the landing—one to finish lower and one to commence upper flight. A variety of this stair occurs when a third flight is put in between and at right angles to the

upper and lower flights; see sketch E, Fig. 83.

616. GEOMETRICAL STAIRS.—Stairs of this class are arranged with an opening or "*wellhole*" between the flights and without newels, the outer string being continuous from bottom to top. An example is shown by sketch A, Fig. 84.

617. CIRCULAR OR SPIRAL STAIRS.—An example of this kind is shown by sketch B, Fig. 84. The steps are all "winders" converging from the outside to



A B FIG. 84

the centre. There are two kinds of circular stairs, viz., ***circular geometrical***; when the stair has an "outer string" and a "well hole"; and ***circular newel***, when the stair has a centre newel into which the steps converge; the sketch shows a circular stair with a newel. The various parts of stairs will be found described in the following articles.

618. STEPS.—Sections of stair steps are shown by the large sketch in Fig. 87 in which T indicates the tops or "***treads***" and **R** the "***Risers***" or faces. A step of this kind of stair would therefore be composed of a tread and a riser. (In very common stairs the riser is omitted so that the step is a tread only). Treads for stairs of ordinary houses are made 1¼in. thick, but for first class work the thickness is made from 1½in. to 1¾in. The outer edge of tread is nosed as shown by the sketches Fig. 87. Risers are made from 1in. thick in ordinary stairs to 1¼in. for the better kind. The large sketch, Fig. 87, shows different methods of jointing the riser to tread. To further strengthen the joint between tread and riser, small blocks are glued and secured in the internal angle, see BL, Fig. 87. Figs. 85 and 86 show

methods, usually adopted, of fixing steps to strings. In Fig. 85 the steps are housed into both strings. In Fig. 86 they are housed into one, and cut, mitred, and bracketed on to the other. In some cases they are cut, etc., on to both strings. The details of methods for securing steps to strings are described in article 619. The ordinary steps in a flight are called "*fliers.*" Those which radiate from a newel or a well-hole are called "*winders.*" The latter should be avoided as much as possible, but where absolutely necessary they should be of the same width as the fliers at 18 inches from the outer string or newel. The "*going*" of a stai is the horizontal distance from face of one riser to that of the next one; while the "*rise*" is the perpendicular distance from top of one tread to the top of the next one above. It should be remembered that steps which are both wide and high are very fatiguing to ascend, so that when designing stairs it is necessary to have a wide tread if the rise is small or *vice versa.*

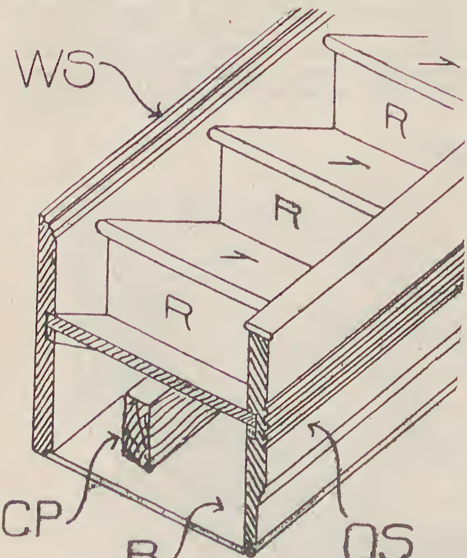


FIG. 85

A very good rule for the proportion is :—Width of tread multiplied by height of riser should approximate to or equal 66 inches The width of the tread should not be less than 9 inches, but in important stairs should be more—12 inch tread and 5½ inch rise giving an ideal step. Sometimes the lowest one of the steps in a stair is made larger than the others, and brought out at the end in a pleasing curve or 'sweep." Such is called a "curtail" step. The construction of a step of this description is shown by sketch B, Fig. 89, by which it will be seen that the outer end of the riser is reduced to a veneer about a ¼in. thick, and bent round and permanently secured to an inside block.

619. STRINGS.—These are the pieces of timber at the sides of a stair flight which support the steps. The piece put against the wall is called the "WALL STRING," while that on the outer side of the flight is called the "OUTER STRING." When a flight is put between two walls both of the side pieces are wall strings. A wall string (WS) and outer string (OS) are shown in sketches Figs. 85 and 86. Strings are classified as follows, according to the method of finishing and securing the steps to them :—

(1) Close or housed strings.
(2) Open or cut ,,

When the steps are let, or housed, into, the string and the top of the latter left so as to be parallel to the lower edge it is called a *close* or *housed string*. Examples of housed strings are shown in Figs. 85, 86, and 87. In sketch Fig. 85 both wall and outer strings are housed. When the outer string is housed, it is finished on the outer surface after the style of the one in the sketch Fig. 85, or it may be set out in imitation of panelling. The large sketch in Fig. 87 shows method of housing and securing the steps in the case of a housed string The sketch is a view from the underside. As will be seen, the steps and risers are housed into the string (S) (to a depth of from ½ inch to ¾ inch, as the thickness of string may allow) and tightened up and held in place by wedges (W) driven in behind them—the whole of each joint being well glued, and the wedges further secured by being nailed to the string. In the sketch Fig. 86 the outer string (OS) is an open one, being "*cut, mitred*

and bracketed." An open or cut string, as its name implies, is cut away so that the end of each step is shown. The sketch B, Fig. 87, is the end of a step on an open string. The corner is removed to show the arrangement of the different parts. (S) is the string on which the tread (T) rests. (R) is the riser rebated on to the string, and carried on so as to mitre with the ornamental bracket (BR). N. is the nosing piece planted on so as to return the nosing of front edge round the end of tread. In some cases the ornamental brackets (BR) (sketch B, Fig. 87, and B sketch, Fig. 86) are omitted. The risers would then be mitred to the

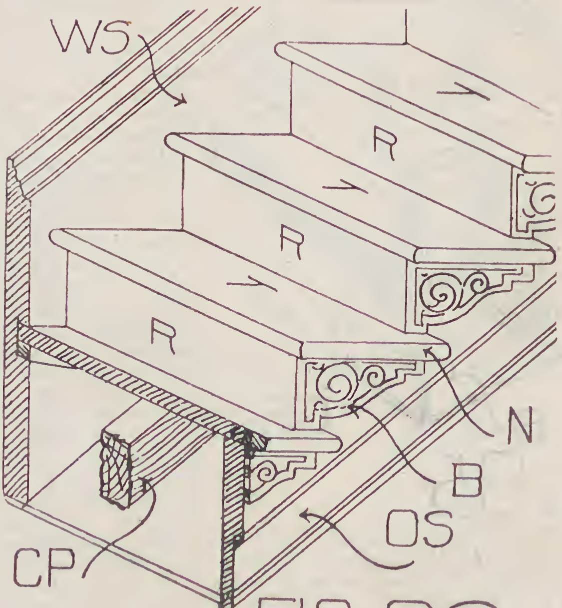
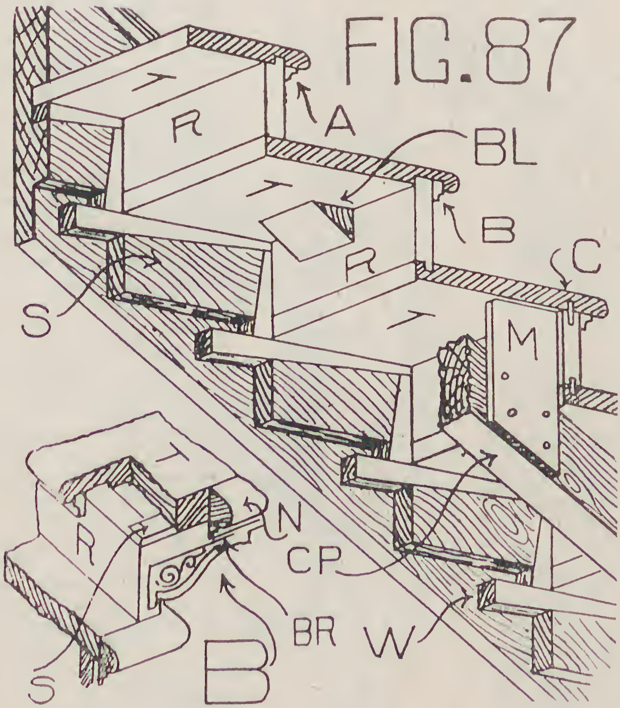


FIG. 86

string instead of rebated, as shown in the sketches. Rough strings or "*carriage pieces*" (CP in sketches Figs. 85, 86, and 87) are put in under the steps midway between the strings so as to form an additional support. They should extend from bottom to top of the flight, and be well secured at the ends. Pieces of timber (M sketch, Fig. 87) are nailed to the carriage pieces and butted up to under surface of each tread. A "*wreathed*" string is one which is continuous—that is without newels up two or more flights. The outer string in the geometrical stairs shown in sketch A, Fig. 84, is an example of a wreathed or continued string for two flights. The wreath, or turn, can be made as shown by the sketch A, Fig. 89. The turning portion of the string is, as shown by the sketch, reduced so that there is only a veneer about ⅛ inch thick on the outside. This veneer is turned on a half cylinder to the double curvature required, and backed up with pieces fitting together like arch blocks and glued. The wreath is then cut for treads and risers. It may be mentioned that the wreath is made separately and then jointed to the straight portions of the string.

620. A FLIGHT is a series of steps one above the other, with landings intervening. The straight stair at A, Fig. 83, is a flight The stair at B, Fig. 83, has two flights. The "going" of a flight is the horizontal distance from face of its bottom riser to face of that at the top. It will be noticed that a flight has one more riser than the number of treads.

621. A LANDING is a horizontal space intervening between two flights, or the space at the top of a stair. Properly speaking, the name landing should be given only to the space at the top of a stair, the others being called spaces The space equal to the width of a flight, as at sketch D, Fig. 87. is called a ¼ space. That equal to width of both flights, as at sketch B Fig. 87. being called a ½ space. Landings or spaces are constructed similarly to floors for which see articles 428 to 448 *ante.*



622. SOFFIT OF STAIRS.—The soffit is the under surface of a flight or landing It may be formed either with plaster, timber or with metal plates. In the case of plaster the laths are secured to edges of strings and carriage pieces (firring being put on the latter to level up if required) and the plaster is put on in the same way as for a ceiling. Timber soffits are formed either with lining boards for ordinary stairs or panelled work for the better kinds. The lining boards may be put on square with the strings, or diagonally, as the taste of the designer may decide. The panelled soffits are framed and panelled on the principle as described in Art. 540 *ante* ; the division and arrangement of the panels being matters controlled by the particular style of the design. Thin metal plates, either of zinc or steel, are being much used for stair soffits. This kind of soffit is to be recommended, for the metal is light and can also stand the vibration of people on the stairs. The plates are made in plain or ornamental designs as the case may require, and secured to strings and carriage pieces; firring pieces being used as required

623. HEAD ROOM.—Provision should always be made for enough of perpendicu-

lar space so that the head of anyone ascending the stairs shall not be liable to catch against the edge of landing or soffit of stairs above. This perpendicular height or space is called the "*Head room*," and it should never be less than 7 feet.

624. SPANDREL.—The triangular space under outer string of the lowest flight of a stair is sometimes filled with boarding or, in the case of good stairs, with panelling, so as to form a cupboard. This filling is called a *spandrel* A panelled spandrel is shown at sketch B, Fig. 83. The panelling would be about $1\frac{1}{2}''$ or $1\frac{3}{4}''$ thick.

625 NEWELS —These are the posts put at bottoms and tops of flights to secure hand rails, etc. Properly speaking, however, the term belongs to the central post from which the winders radiate in a circular newel stairs. Newels are shown in the sketches Figs. 83, 84 and 88. As a rule the portions not occupied by the abutments of strings and handrails are turned or square moulded and the tops rounded off as spheres or ovals. In common stairs the newels are plain, the edges being stop chamfered. In stairs of imposing character, such as those for public buildings, the newels are the portions to receive special ornamentation and they are turned, moulded and carved in the most elaborate manner. The strings are housed and tenoned into the newels and the joints secured with pins and glue. Newels at landings are notched on to the outer joist of the latter. Some idea of the relative positions of string newel and landing may be obtained by the sketch Fig. 88, which represents a top corner of a flight in an open newel stair. N is the newel, the top part of which is cut off. S. is the string. The outer joist of the landing is shown at J covered by a fascia board (F) B B are lower portions of balusters. In this case the bottom of the newel is finished with a "drop," *i.e.*, a moulded or turned end. The newel at top of lower flight is sometimes carried down to the floor as shown at sketch B, Fig. 83. Newels are made upwards from $4'' \times 4''$ in cross section; $6'' \times 6''$ being a common size.

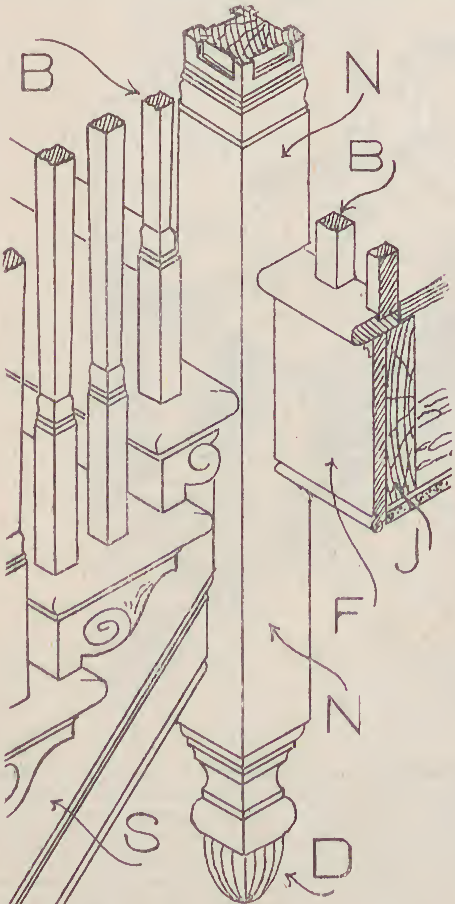
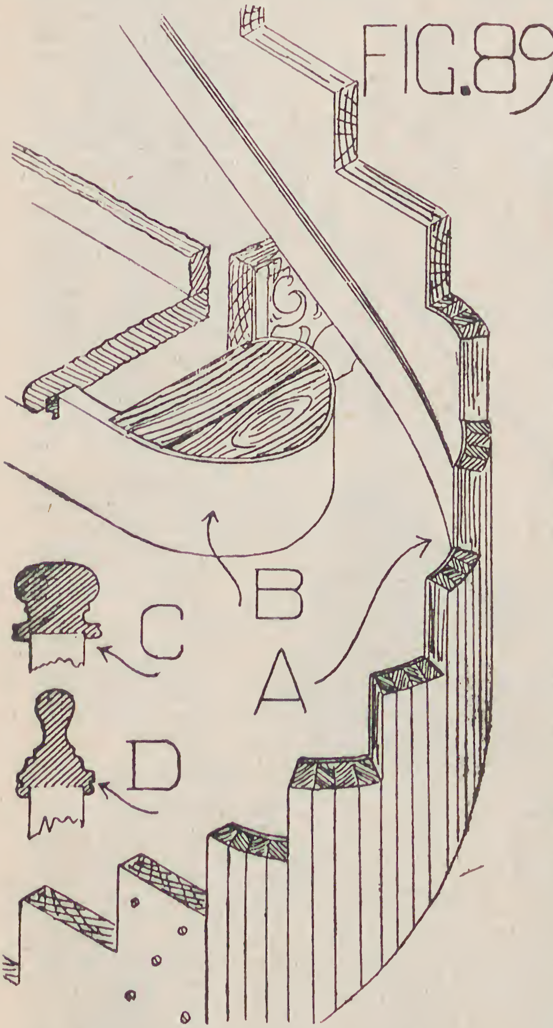


FIG. 88

626.—HANDRAILS AND BALUSTERS.—The handrail is the piece of timber put at a

convenient height for the hand at the side to act as a support during ascent, and to prevent falling over side of stairs. The rail should be parallel to line of nosings of each flight, but may be curved at ends, so as to make a graceful finish against newels, as shown in sketches B, Fig. 83, and A, Fig. 84. When the rail is continuous, as for geometrical stairs (see sketch A, Fig. 84) it is called a *Wreathed Handrail*, the portion at the turn being the "wreath." An ogee bend like that at the top newel in sketch B, Fig. 83, is called a *swan's neck.* A single turn, convex in form, is called a *knee*, while a concave turn is called a *ramp.* Handrails range in cross section, from a plain oval to the elaborately moulded. Small sketches of cross sections of handrails of common patterns are shown at C and D, Fig. 89. A very good style of handrail is shown in cross section by sketch B, Fig. 90. The main consideration is to have the top of rail of a shape that it may be comfortably grasped by the hand, and there should be no sharp edges in this portion. Handrails for common stairs may be 4 inches deep and 3 inches wide, the top being reduced to a round about $2\frac{1}{4}''$ in diameter. The top of the handrail should be 3 feet above landings, while the height above nosings should be about 2″ 7½′. The handrail should be housed and tenoned into the newels.

FIG. 89



627. **Balusters** are the small posts, placed at frequent intervals to support the handrail, and also to help to prevent falling over the side of the stairs or landings. Balusters range upwards from $1\frac{1}{2}'' \times 1\frac{1}{2}''$ in cross section; $2'' \times 2''$ being the usual size. They are either plain or moulded to match the newels. If the string is an open one the balusters are either housed or dovetailed into the treads, see sketch, Fig. 88. When the outer string is close or housed, as at Fig 85 the balusters would be cut on to the upper edge. In stairs of a good description the portion of close string between the baluster is moulded, as at Sketch A, Fig. 90. The best way to secure the balusters to the handrail is by means of an iron bar, the width of

the balusters, about a quarter inch thick, and of the length of the rail, and secured with a screw to head of each baluster and also by screws at frequent intervals up into the rail. A cross section of a handrail and balusters secured in this way is shown at Sketch B, Fig 90. In common stairs the heads of the balusters are nailed to the handrail. When the string is an open one, two balusters are put on the end of each tread, as shown by the Sketch, Fig. 88; but in any case the balusters should not be spaced more than 5 inches apart. Balusters are often made of cast iron, and in very good work the space between string and handrail is fitted with wrought iron or brass work with the very best results.

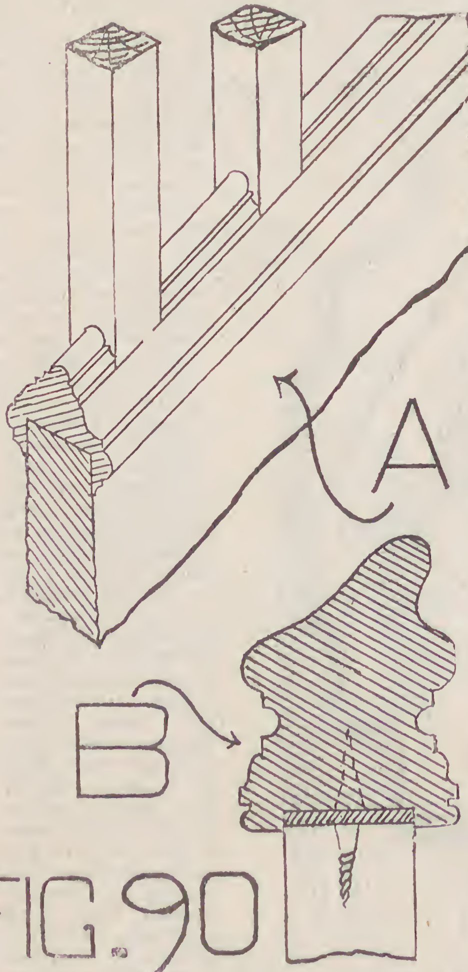


FIG. 90

628. TIMBER FOR STAIRS.—The following timbers are used for this purpose:—

Painted work: Kauri, Oregon, Colonial Pine, Colonial Beech.

Polished or varnished work: Cedar, Blackwood, Rosewood, Red Bean and Colonial Beech

SHOP FRONTS.

629. SHOP FRONTS, though differing in matters of detail, are all very much the same as regards general arrangement and construction The sketch Fig. 93 shows half plan and elevation of a typical shop front with two windows; the entrance door being in from the line of the front. The stiles for the door frame are made of large scantling (about 6″ x 6″) so that they may afford ample abutment for the window sashes; and they are carried up either to the level of soffit over entrance, or to shop ceiling. In a door frame of this kind the head as well as the transom would be tenoned into the stiles Casements as shown in the sketch, and as at G, Fig. 78, or sash doors in one leaf as at F, Fig. 78 are the kinds of doors usually used for shop entrances. Solid panelled doors like those at B, Fig 78, or M, Fig. 77, are sometimes used. For detail description of doors and door frames see Arts. 545 to 580.

630. SHOP WINDOWS.—The sketch Fig. 91 shows isometrical views of portions of shop windows The vertical section is on a vertical plane taken through at the position indicated by the line C D on the plan in Fig. 93, while the horizontal section is made at the level of E F. Linings (L) about $1\frac{1}{2}''$ thick, with nos-

ing or ovolo on outer edges are secured by means of plugs to sides of piers. The tops of these linings are grooved into the soffit (S F) of the casing of the girder (G) which spans the opening. The timber sill (S L) is put resting on a slate or marble nosing (N) which in its turn rests on a brick work base. Sometimes the base is of masonry and the nosing omitted, the sill being put directly on the base. The scantling of the timber sill may be about 8 or 9 inches high and 7 or 8 inches wide; the outer surface being moulded as shown. This sill is housed into the lining against which it abuts, mitred at the corner and housed at the inner end into the door post The bottom rail (B M) of the sash is put resting in a rebate on the top of the sill. The section sketch B. Fig. 92, shows a method adopted when the bottom rail of sash is to be at some height above the base course. S J is a piece of framed work called a stall board; the panel being generally a cast iron grill so as to allow of ventilation. S L is the sill on which the bottom rail (B M) rests. In cases where the building has a basement the stall board is formed of swinging sashes with glass in them, as shown by large sketch. Fig. 92, so that light and ventilation may be obtained for the basement. The shop window sashes are made with stiles (S T) bottom rail (B M) and top rail (T R) (sketches in Figs 92 and 93) rebated and moulded like an ordinary sash (excepting of course that the rebates and mouldings are on a larger scale) and they would be jointed together as shown in Fig. 82. The top of the bottom rail is however, generally bevelled instead of moulded. The usual sizes of parts of a shop window sash are as follows: —

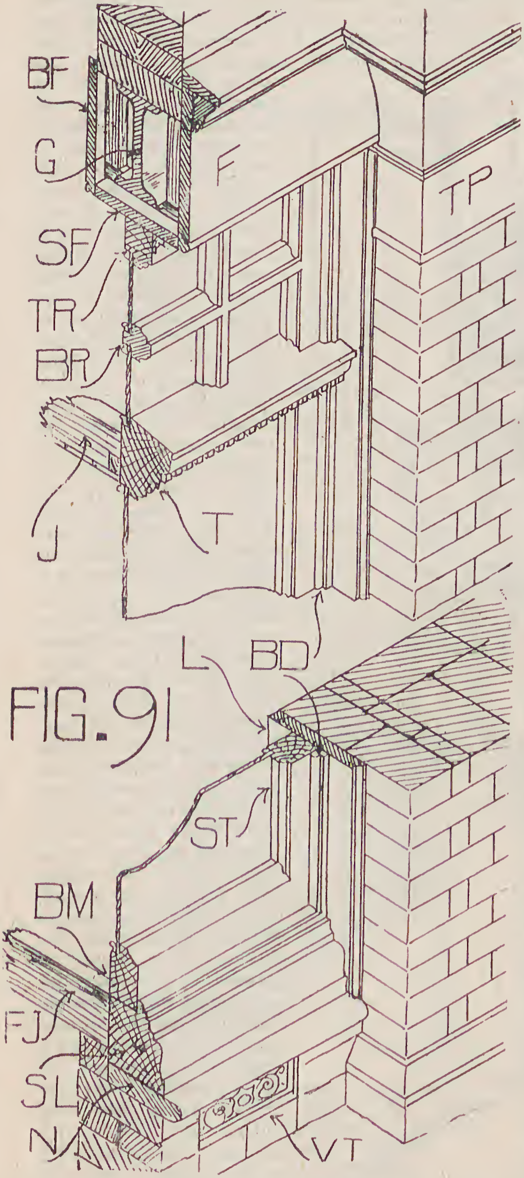


FIG. 91

Bottom rail	6″ x $2\frac{1}{2}$″
Stiles	4″ x $2\frac{1}{2}$″
Top Rail	,, ,,

It is the general practice to divide the upper part of the sash into a number of smaller panes. This is done by putting in a transome (T) and bars (B R) as shown in the sketch, Fig. 91. The glass should be fastened in the shop window sashes with beads, secured with screws, as shown in the sketch. In very large windows the best plan is to have the rebate for the glass on the outside: the beads being part of the moulding. A small bead or ovolo (B D) to match top mould of sill and to intersect with it is put round joint of sash with lining. The sash at each side of the entrance is of course made the same way and either the two stiles mitred together at the corner, or an angle bar, as shown by sketch B. Fig. 93, is put in The front of the casing of the girder forms a fascia and is ornamented with mouldings and capping piece. The space over the area between the shop door and girder is usually ceiled with a framed and panelled soffit If the shop front is unprotected by a verandah the capping of the fascia should be covered with lead, and flashed to the wall above. Revolving shutters formed with thin timber or iron laths hinged together are used for the protection of shop windows. They are rolled up on a spring roller into a space either under or in front of the girder which spans the opening of the shop front. The upper part of the large sketch, Fig. 92, shows an example of the roller put under the girder. The recess is formed by keeping the soffit board down for some distance from the bottom flange, the fascia being deep enough to reach the soffit. The edges of the shutter would be guided up or down by running in a groove (G R) in the linings against the piers. If in separate pieces for window and door entrance the edges of the shutter are run in grooves in a column fixed at the angle of the sashes

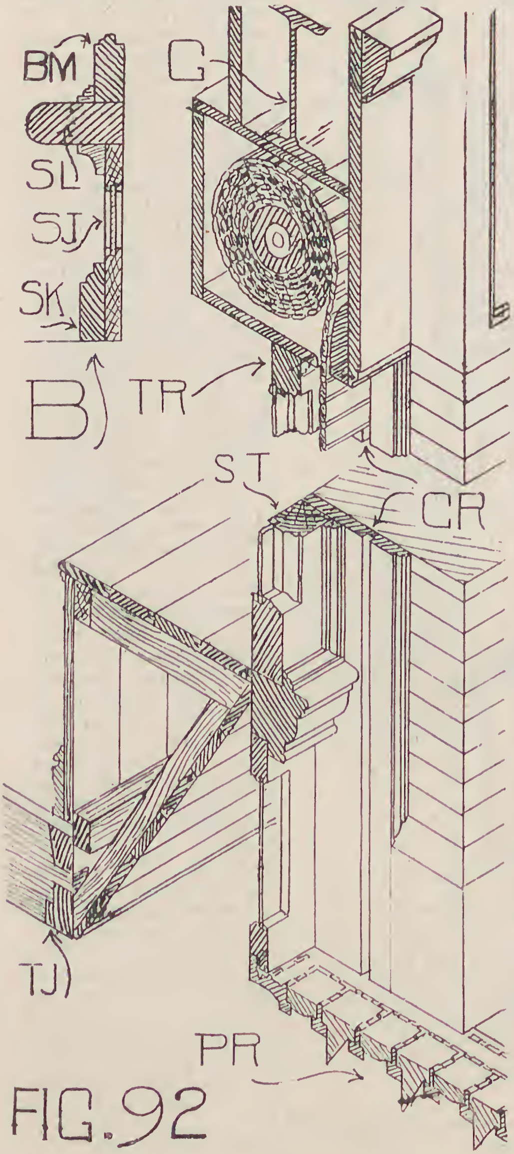


FIG. 92

or in a movable vertical piece. which is taken down when the shutters are rolled up.

631. THE SPACE BEHIND the window sash in which the goods are displayed is ased in at the back with a partition put across in line with the entrance door. as hown by the plan in sketch Fig. 93. As a rule the partition is partly boarding

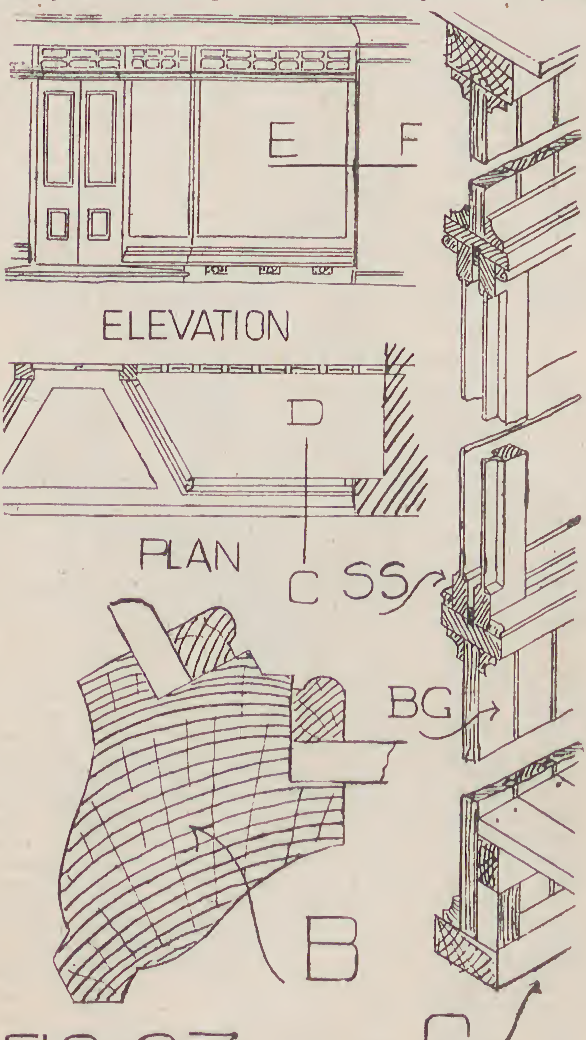


FIG. 93

and partly sliding sashes. The sketch C., Fig. 93, shows a section of such a partition. The top and bottom rails or plates are of 4in. x 2in., while the sliding pieces for the sashes to slide between are $5\frac{5}{8}$in. x $1\frac{1}{4}$in. The upright boards are 4in. x 1in. or 6in. x 1in., tongued and grooved and beaded, and are kept in place

at the ends between ovolo or Scotia mouldings nailed to the plates and to the sliding pieces. The sashes (SS) are 1½in. thick. and slide between stop and parting beads on the sliding pieces, as shown by the sketch. The lower part of the Sketch C, Fig. 93, shows floor of the window coming up against the partition. The height of the bottom of the sliding sashes is usually about 3ft. from the floor of the shop, while the sashes themselves would be about 5ft. high. The partition would be carried either right up to the shop ceiling or up to the level of the transom of the window sash, a window ceiling being put over at this level. The Sketch, Fig. 91, shows a ceiling joist (J) of a window ceiling at the level of the transom. The partition carried up to the level of the transom of a window ceiling is the best, because the shop can be lighted and ventilated from the portion of the shop window above the transom. In large windows the sliding sashes are not used A partition composed of 3in. x 2in. or 4in. x 2in. studs and rails, with upright boarding to a height of 6 or 7 ft., and the remainder of glass in fixed sashes being adopted instead. In such a partition access is got to the window space by a ledged door about 1ft. 6in. or 1ft. 9in wide, put in the lower part. In shops such as chemist's. jeweller's, confectioner's. &c., where the fittings are of the cabinet work class the casing in of the window space is done in a very much better style than just described, but the examples given are those used in the majority of shops.

SHOP COUNTERS AND PARTITIONS.

632. **Shop Counters.**—Sketches A and B, Fig. 94, are examples of shop counters. Sketch B is a cross section of a plain counter, made with 3″ x 2″ framing, top about 1¼″ thick, with a thumb mould on outer edge, and a front composed of 4in. x 1in. or 6in. x 1in., tongued and grooved and beaded, or V jointed, upright boarding, finished at the lower part with a skirting. There are many methods of framing up the inside frame, but the most common is to have a frame back and front. each composed of 3in. x 2in. top and bottom pieces and uprights, the latter being spaced about 4 feet apart and tenoned into the former. The back and front frames extend each the whole length of the counter. and are connected together by cross-bearers, also of 3in. x 2in., placed top and bottom at the positions of the uprights. The cross bearers are tenoned or dovetailed into the tops and bottoms of front and back frames. Cross bearers are also put in to carry the shelves. The inside has a floor about 4 inches up from floor of shop. and either one or more shelves between the floor and the top. The sketch shows an example with one shelf inside. The sketch A is an example of a more elaborate counter. The framing of the inside is very similar to that of the plain kind just described, but the front is framed and panelled work with a slope inwards towards the bottom. The thickness of the panelled work is about 1½in., and the panels are ½in. thick with colection mouldings. Sometimes the panels are raised as described in Art. 571, and shown by sketch D, Fig. 77. For detail description of framed work and finish of panels see Arts. 540, and from 567 to 572 and sketches A, B, C and D, Fig 77. Curved and fluted pilasters are planted on to and secured to the front at intervals of about 4 feet, the skirting of the lower part of the counter being returned round their lower portions. The top should be 1½in. thick with the outer edge moulded. The sketch shows the principle of the general finish of such a counter. The design can of course be varied by having the front perpendicular, and straight instead of curved pilasters can be used. The usual height of a shop counter is 3 feet, while the width is about 2ft. 6in Counters for special kinds of business premises are sometimes higher and narrower, as for an hotel bar, while in other cases while not being higher they are very much wider, as for a bank.

633. **The kinds of timber** used for counters are as follows :—

Inside framing, Baltic, Oregon. Kauri or Colonial Pine.

Tops. Kauri, Cedar. Blackwood.

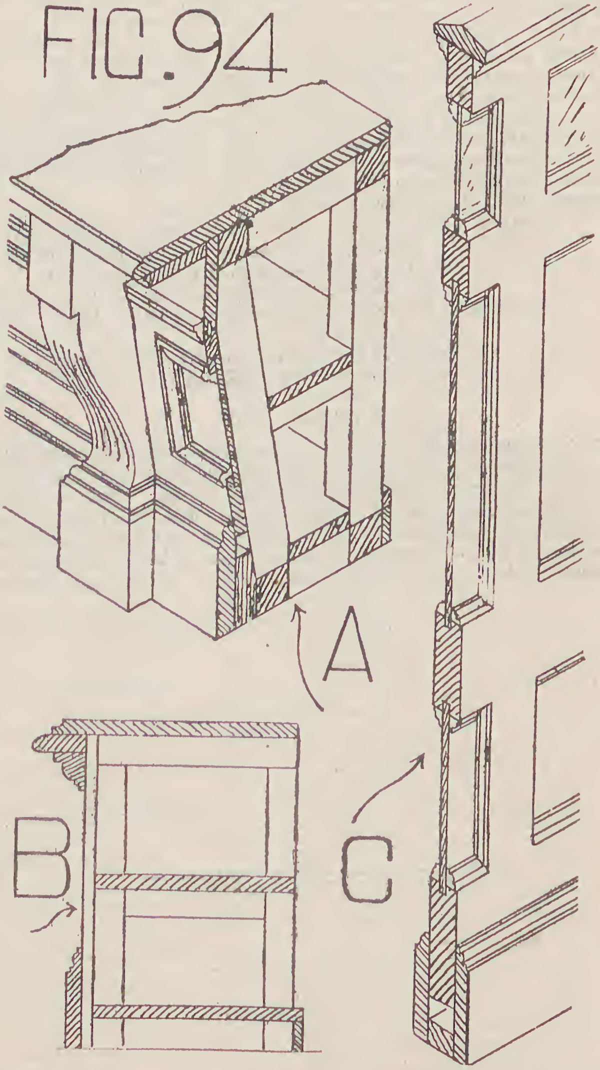
Note. The tops should be polished if possible, as paint will wear off.

Fronts. *Varnished or polished work* : Cedar, Blackwood, Colonial Beech, Red Bean, and others of the fancy and figured Australian timbers. Kauri Pine and imported fancy timbers are also used.

Painted work, Redwood, Kauri, Oregon, Baltic, or Colonial Pine.

634. PARTITIONS.—Only partitions used for dividing shops and offices will be noticed under this head, those for lath and plaster work, etc., having been dealt with in Art. 518. Common partitions are made with 3in. x 2in. or 4in. x 2in. studs and rails and upright 4in. x 1in. or 6in. x 1in. tongued and grooved and beaded or V jointed boarding. The studs are spaced about 3 or 4 feet apart and rails at bottom and top. If the partition is of considerable height intervening rails

FIG. 94



are put at about 6 feet apart. The boards are secured by being let into grooves in the rails and studs or with beaded fillets or mouldings at both sides, as shown in the sketch C, Fig. 93. When the boards are let into grooves the edges of the studs and rails are either beaded or stop chamfered. Partitions made on the same

principle as above but with the upper part composed of glass in sashes, the latter fixed with stop beads, are also much used and can be recommended where division, without excluding light, is needed. A better class of partition such as used for subdivision of office and counting house rooms is shown by sketch C, Fig. 94. Such a partition would be composed of framed work about 1¾in. thick, the panels being either flat or raised, finished with either bolection or sunk mouldings. For description of framed and panelled work see Art 540 *ante* and for panels see Arts. 567 to 572 *ante* and sketches A, B, C, D, Fig. 77. In the example shown the upper panels are of obscured glass secured in place with beads. Skirting boards are put on each side at the joint of the partition with the floor. A partition like the one in the sketch C, Fig. 94, would be from 6 to 8 feet high and would have the top finished with a moulded capping piece. Sometimes framed and panelled partitions are carried right up to the ceiling, in which cases they require to be stiffened at intervals with stout studs, the framed and panelled work being put in sections in between the studs.

635. **Timbers used for partitions** are as follows :—

COMMON PARTITIONS. Clear Pine, Baltic, Oregon, Kauri, and Colonial Pine. If sashes are included the timbers set out for painted work in Art. 597 are used. Moulding and beads are generally made of Redwood.

FRAMED PARTITIONS. *Painted work* : Baltic Pine, Clear Pine, Kauri, Redwood.

Varnished or polished work : Cedar, Rosewood, Blackwood, Colonial Beech, Kauri.

ANGLE BEADS.

636. **Angle beads.**—These are the roll shaped pieces of timber (usually redwood) put at the salient vertical angles inside the building to serve first as guides for the plasterer and permanently as beads for the corners. They are not complete rolls, a quarter being removed so that they may fit on the right angle corners of the brickwork. They are nailed to plugs put in the brickwork at intervals of about 18 inches and should be perfectly plumb. The plasterer finishes his work so that a quirk is left on each side, thus forming a returned bead at the corner.

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